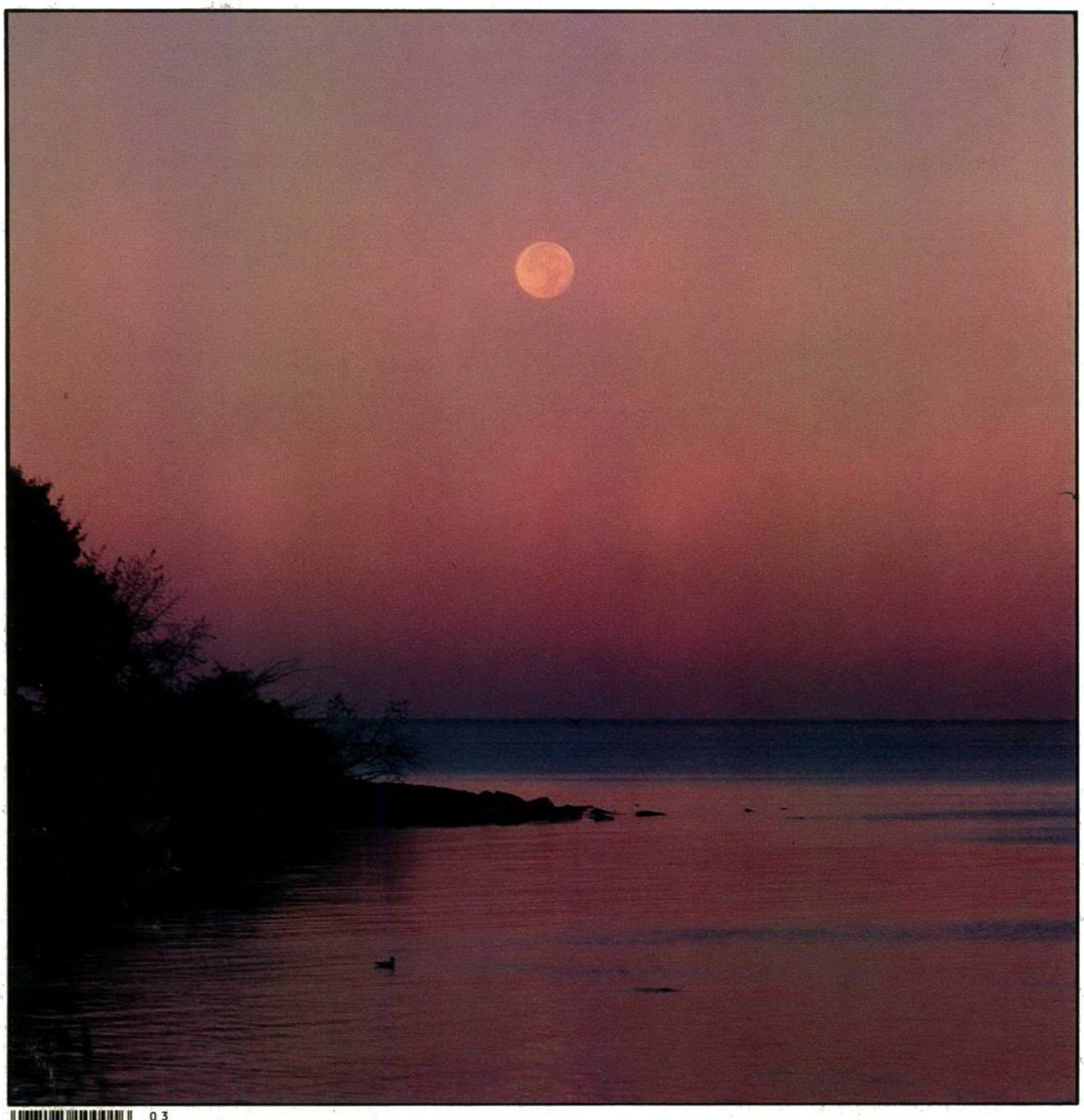
ASTRONOMY

March 1981
$2
UK 95p

Venus: A World Revealed

"Bare-Bones" Astrophotography

What's Happening to Amateur Astronomy?



Lake Ontario Moonrise

Meade System 2000

Think of the dimensions a truly research-quality instrument would add to your observing program.

Then consider moving up to the quality and performance of a Meade 4-inch or 8-inch Schmidt-Cassegrain. For Meade Schmidt-Cassegrains, both optically and mechanically, really are the finest instruments of their kind ever offered the serious observer and astrophotographer.

And, as parts of a wide-ranging system, they are instruments that will grow with your expanding horizons.

Standard Equipment: No other commercially available Schmidt-Cassegrains offer such a list of important technical advantages, much less as standard equipment included in the Base Price:

Worm gear drive systems, on both 4" and 8" models, for extremely low photo-visual periodic error and zero backlash. ☐ Ball bearings on both Declination and Polar Axes, permitting microsmooth tracking and precise balancing, even with the addition of auxiliary systems on the main telescope. ☐ On 8" models, an oversize 8.25" primary mirror, for a wider fully illuminated field, and to reduce the "edge darkening" of Schmidt-Cassegrains which use standard 8" diameter primaries. ☐ Multi-Coated Eyepieces, to maximize light transmission through the ocular lenses. ☐ A standard right-angle viewfinder on 8" telescopes, for comfortable object sighting, and yielding identical image orientation as in the main instrument in the normal observing mode.

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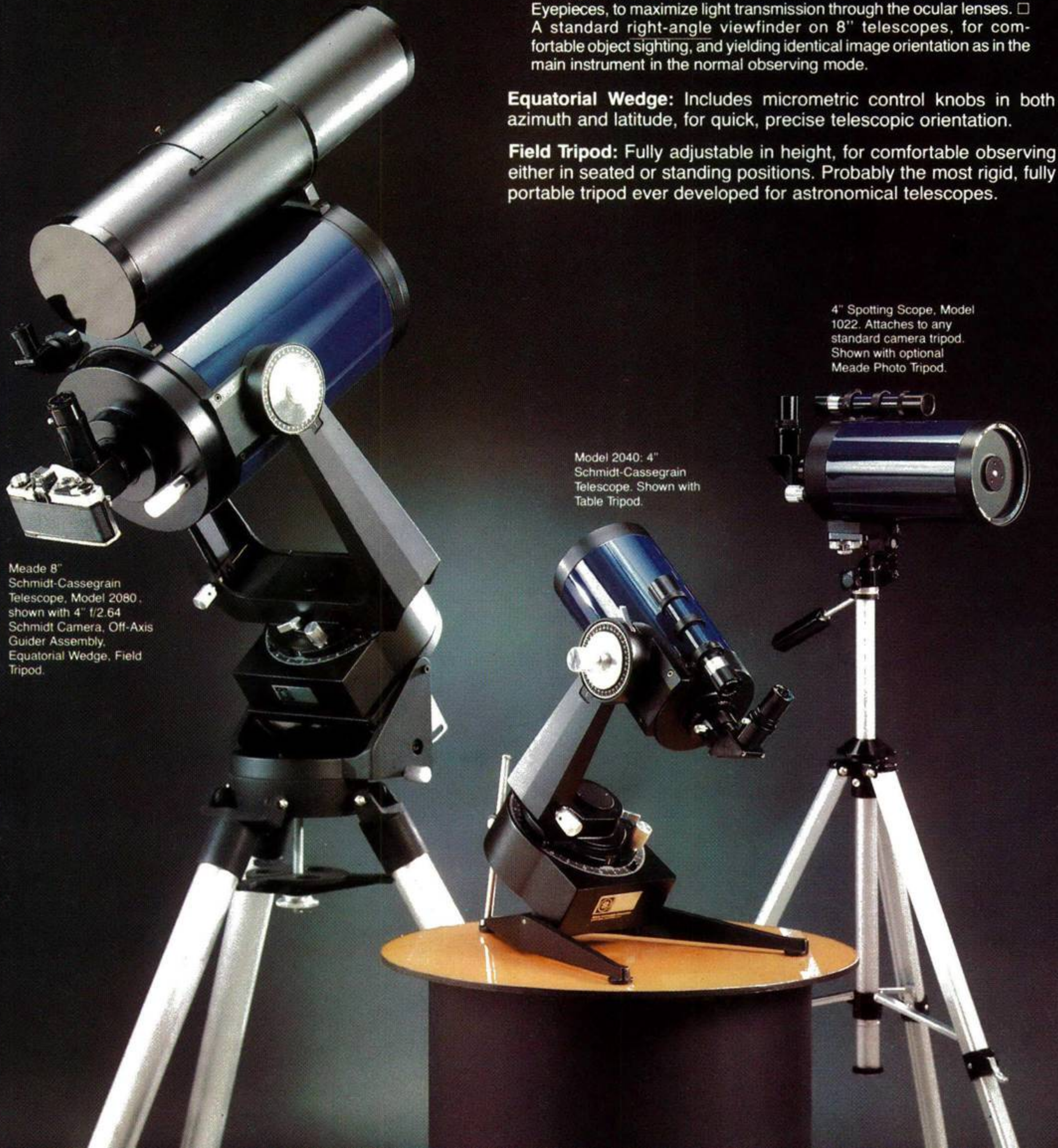


Meade 8" Schmidt-Cassegrain Telescope, Model 2080, shown with 4" f/2.64 Schmidt Camera, Off-Axis Guider Assembly, Equatorial Wedge, Field Tripod.

Model 2040: 4" Schmidt-Cassegrain Telescope. Shown with Table Tripod.

4" Spotting Scope, Model 1022. Attaches to any standard camera tripod. Shown with optional Meade Photo Tripod.

Schmidt-Cassegrains

The System: Perhaps most importantly of all, Meade System 2000 Schmidt-Cassegrains are part of a wide and versatile system: the amazing 4" f/2.64 Schmidt Camera; 4" Schmidt-Cassegrain Photo-Guide Telescope with Illuminated Reticle Eyepiece; Dual-Axis Drive Corrector, and more — all of which attach easily and directly to 8" models.

Aesthetic Design: In the beauty of their enameled deep-blue tube surfaces, in the fineness of their machine-tooled mechanical components, Meade System 2000 models are light years ahead of the competition. See the System 2000 for yourself, and no further explanation will be necessary.

Warranty: As with all Meade products, the System 2000 is fully covered by the Meade One-Year Limited Warranty. See the Meade catalog for full details on this no-risk protection of your investment.

PRICE LIST

Model 2040:	
4" Schmidt-Cassegrain Telescope with Fork Mount ...... Base Price	**$545**
Model 2080:	
8" Schmidt-Cassegrain Telescope with Fork Mount ...... Base Price	**785**
Equatorial Wedge 4"/8"	**50**
Field Tripod 4"/8"	**140**
Table Tripod 4"	**35**
Table Tripod 8"	**45**
Model 1020: 1000mm f/10 Telephoto Lens	**325**
Model 1022: 4" Spotting Scope	**395**
Meade Photo Tripod for Models 1020 or 1022	**50**
Model 2066: 4" f/2.64 Schmidt Camera	**435**

All prices include packing. Complete telescopes are packed in luggage-quality foam-lined carrying cases. All prices F.O.B. Costa Mesa, California. Calif. residents add 6% sales tax.

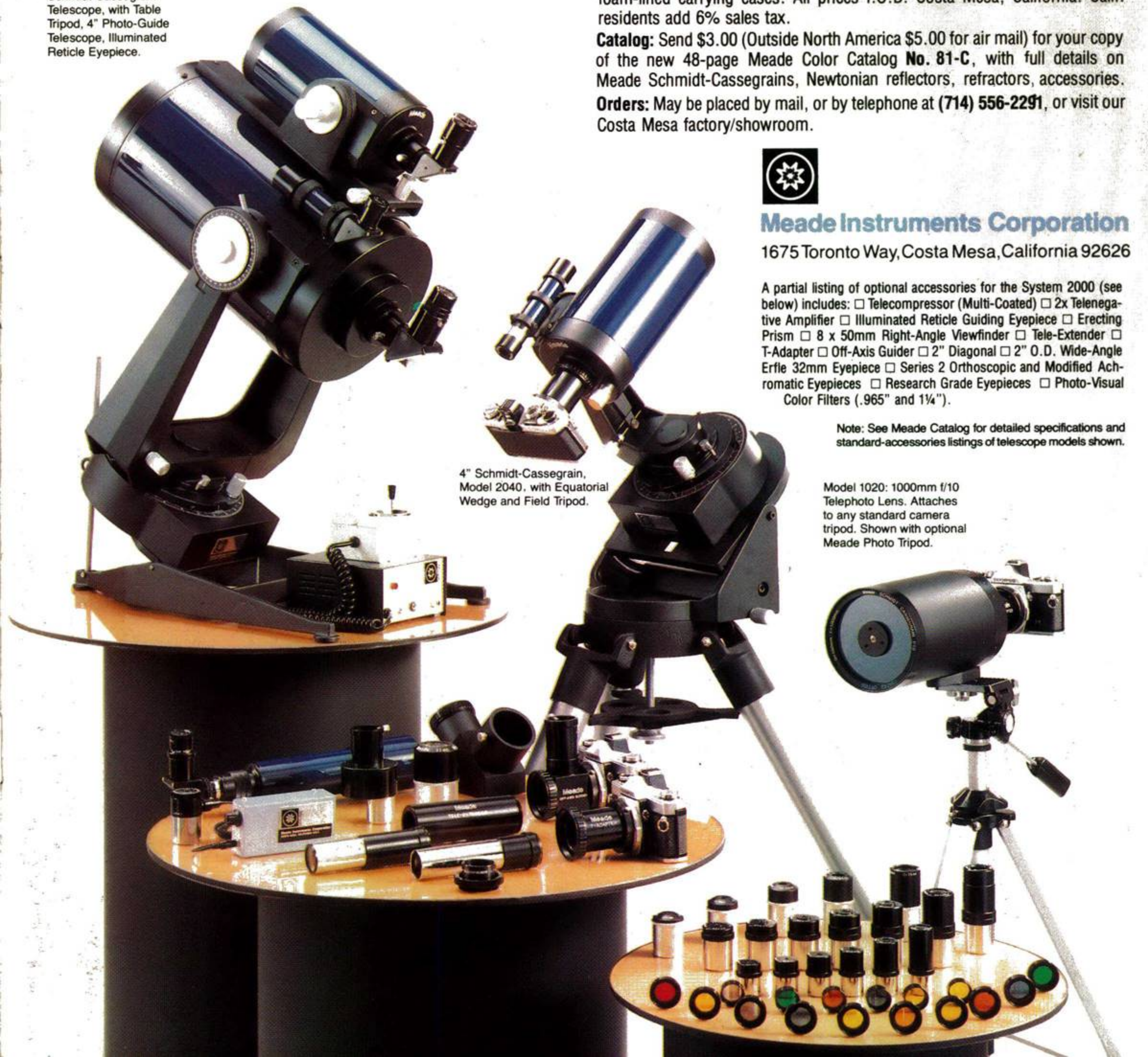
Catalog: Send $3.00 (Outside North America $5.00 for air mail) for your copy of the new 48-page Meade Color Catalog **No. 81-C**, with full details on Meade Schmidt-Cassegrains, Newtonian reflectors, refractors, accessories.

Orders: May be placed by mail, or by telephone at **(714) 556-2291**, or visit our Costa Mesa factory/showroom.

Meade Instruments Corporation
1675 Toronto Way, Costa Mesa, California 92626

A partial listing of optional accessories for the System 2000 (see below) includes: ☐ Telecompressor (Multi-Coated) ☐ 2x Telenegative Amplifier ☐ Illuminated Reticle Guiding Eyepiece ☐ Erecting Prism ☐ 8 x 50mm Right-Angle Viewfinder ☐ Tele-Extender ☐ T-Adapter ☐ Off-Axis Guider ☐ 2" Diagonal ☐ 2" O.D. Wide-Angle Erfle 32mm Eyepiece ☐ Series 2 Orthoscopic and Modified Achromatic Eyepieces ☐ Research Grade Eyepieces ☐ Photo-Visual Color Filters (.965" and 1¼").

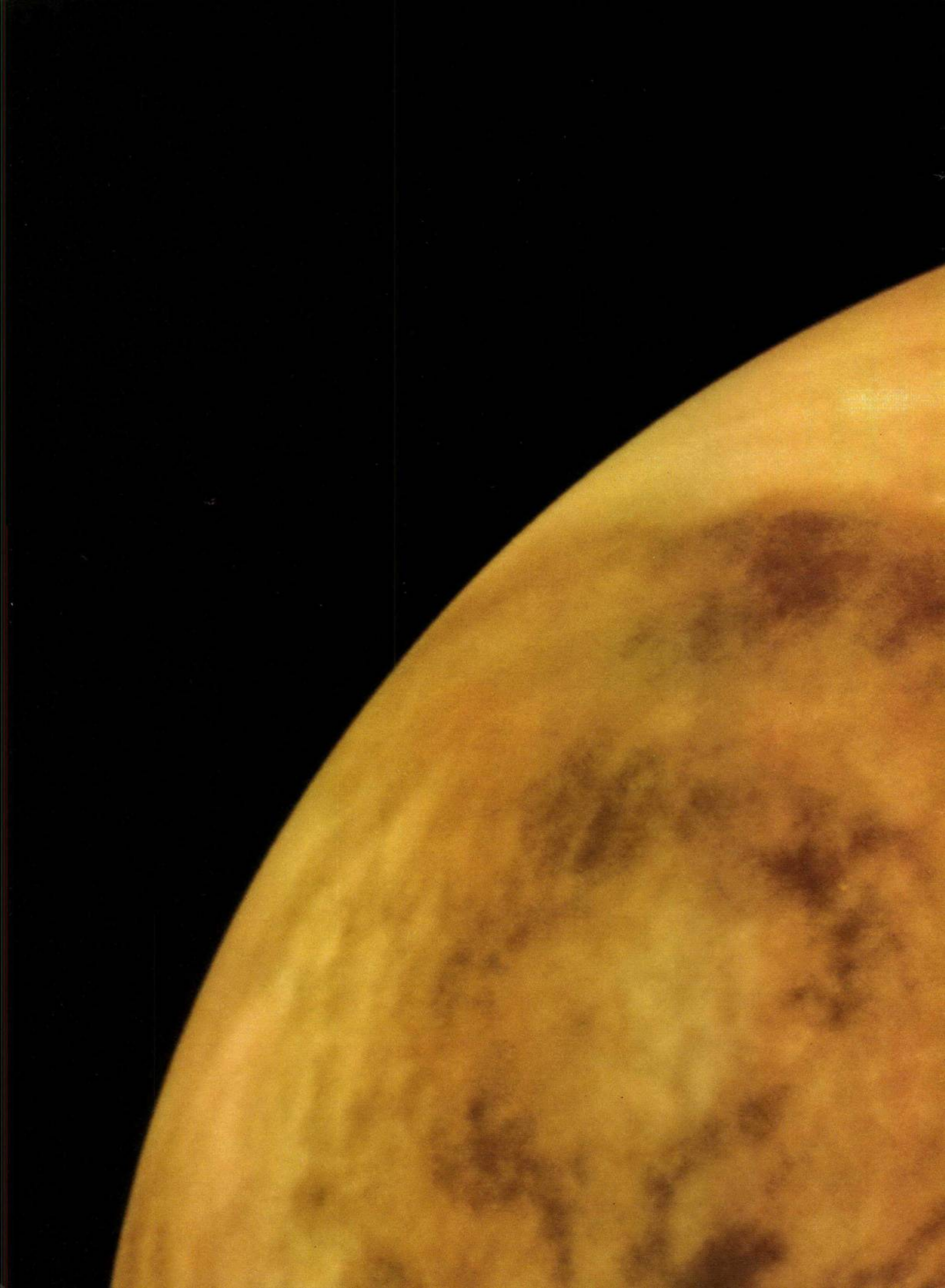
Note: See Meade Catalog for detailed specifications and standard-accessories listings of telescope models shown.

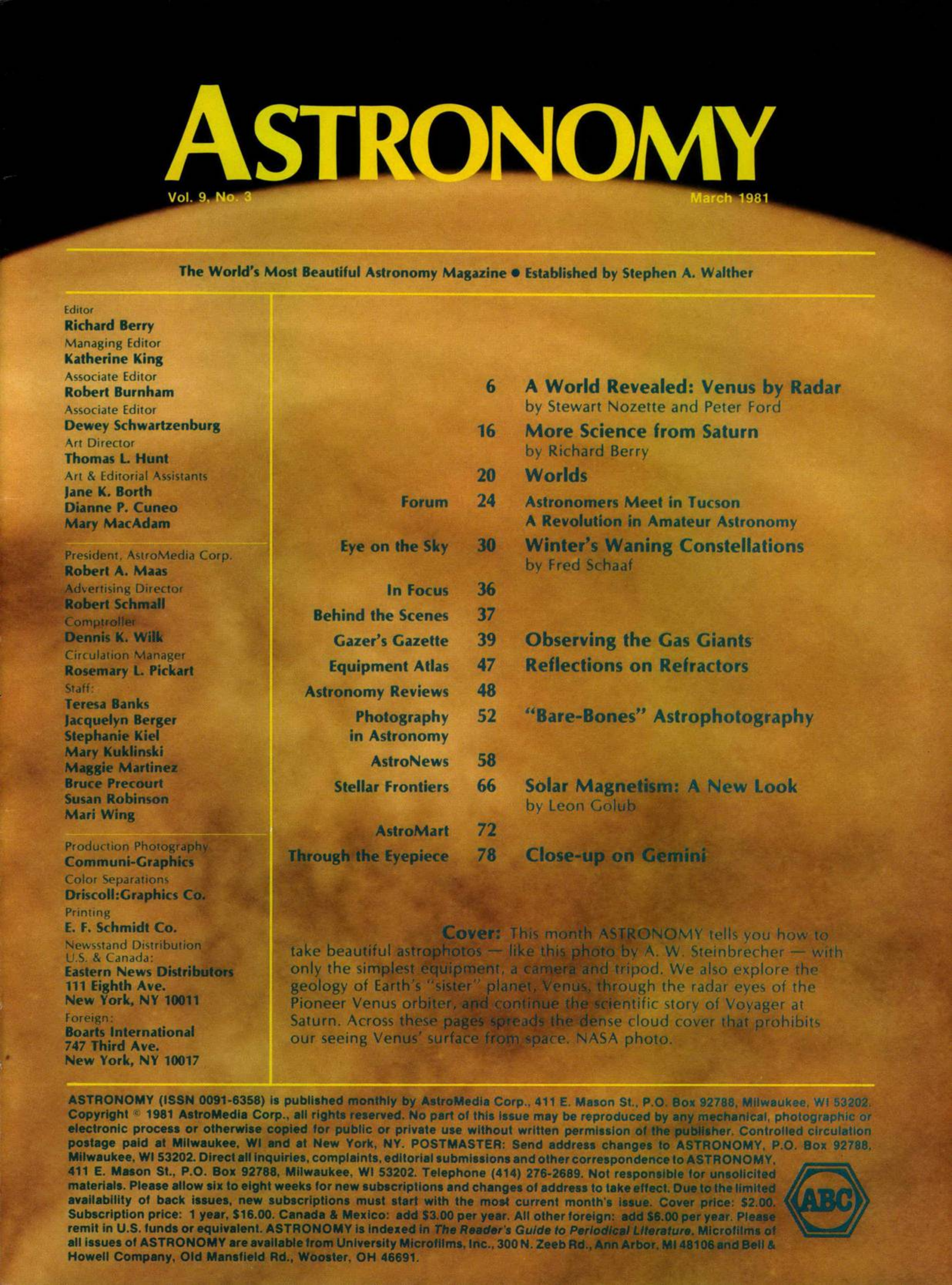


Model 2080: 8" Schmidt-Cassegrain Telescope, with Table Tripod, 4" Photo-Guide Telescope, Illuminated Reticle Eyepiece.

4" Schmidt-Cassegrain, Model 2040, with Equatorial Wedge and Field Tripod.

Model 1020: 1000mm f/10 Telephoto Lens. Attaches to any standard camera tripod. Shown with optional Meade Photo Tripod.





ASTRONOMY

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Cover: This month ASTRONOMY tells you how to take beautiful astrophotos — like this photo by A. W. Steinbrecher — with only the simplest equipment, a camera and tripod. We also explore the geology of Earth's "sister" planet, Venus, through the radar eyes of the Pioneer Venus orbiter, and continue the scientific story of Voyager at Saturn. Across these pages spreads the dense cloud cover that prohibits our seeing Venus' surface from space. NASA photo.

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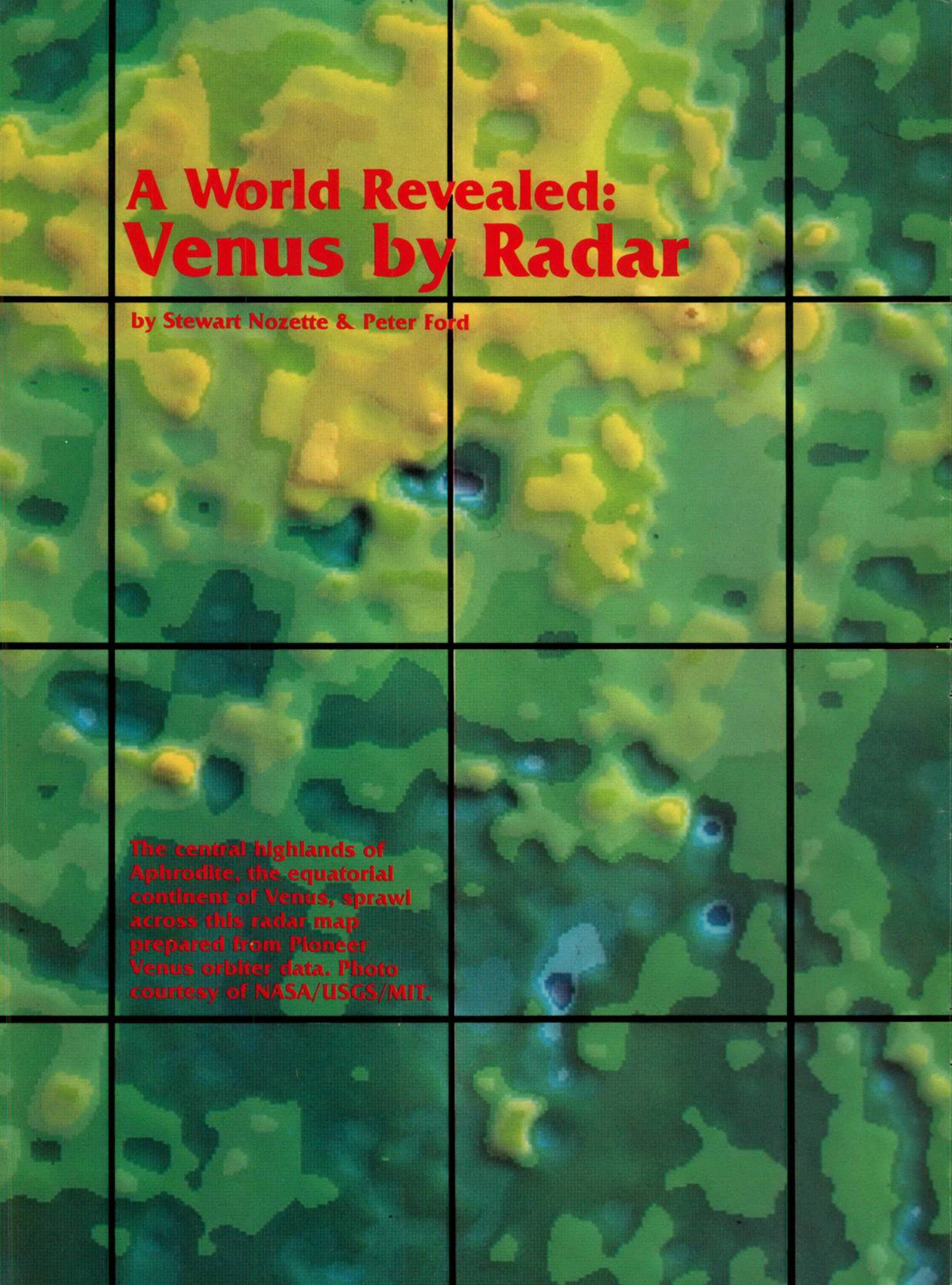
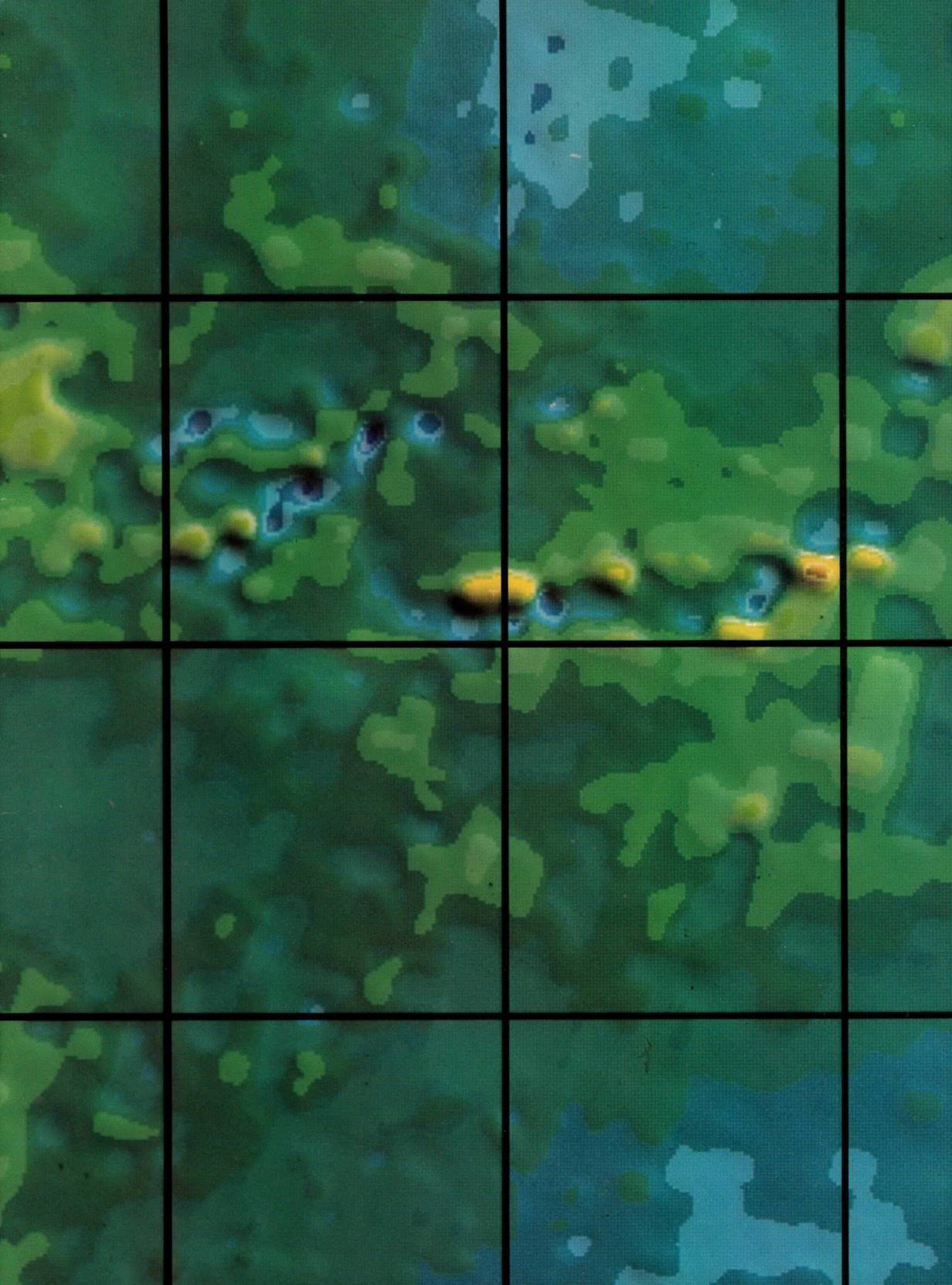
ABC

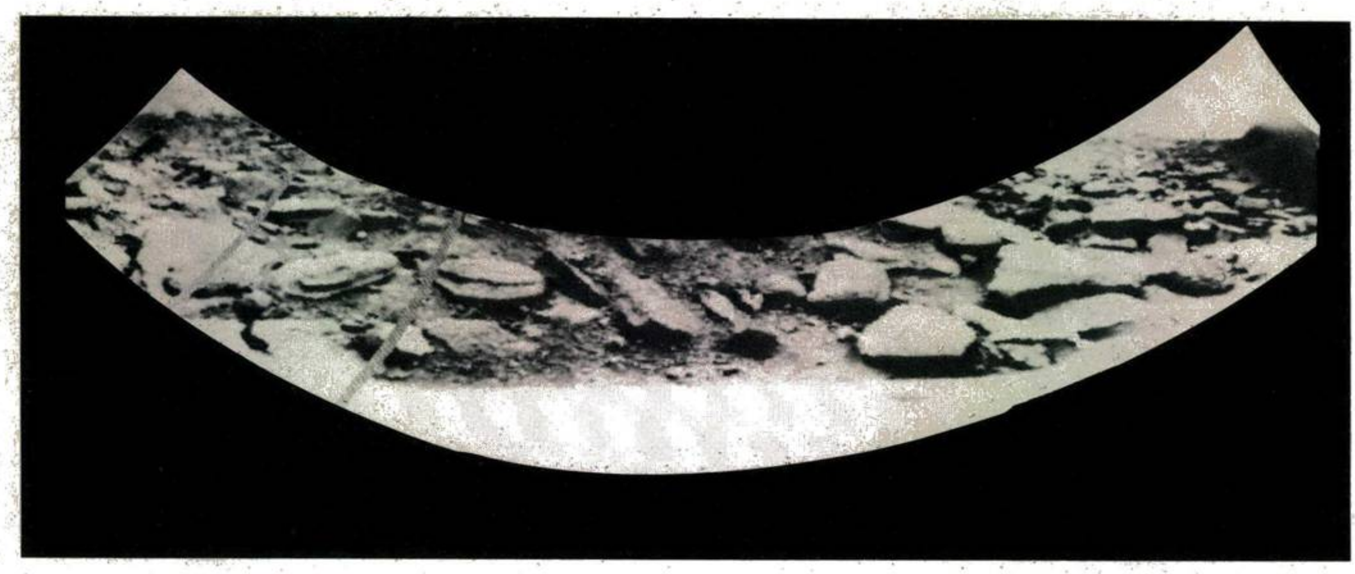
A World Revealed: Venus by Radar

by Stewart Nozette & Peter Ford



The central highlands of Aphrodite, the equatorial continent of Venus, sprawl across this radar map prepared from Pioneer Venus orbiter data. Photo courtesy of NASA/USGS/MIT.





On the surface of Venus to the east of Beta Regio, the Soviet probe Venera 9 took this panoramic photograph of rocks and gravel next to its landing site. The horizon shows at top left and right. Photo by Novosti.

The past ten years or so have witnessed an explosive growth in our knowledge of the solar system, so much so that perhaps we forget one of the glaring gaps: Venus, our closest planetary neighbor, has been the target of 12 Soviet and five American space missions and yet its surface features have still remained largely a mystery. A dense atmosphere and thick cloud layers prevent a direct view. In visible light, all you see is a featureless disk — only in the ultraviolet do low-contrast cloud patterns appear.

This deficiency in our knowledge of Venus' surface becomes almost painful when you compare it with what we know about the other planets. The surfaces of Mars and its two tiny moons have been mapped in great detail, along with those of our own Moon, one hemisphere of Mercury, the Galilean satellites of Jupiter, and nearly all the moons of Saturn. We have seen parts of Mars and Mercury at resolutions approaching 100 meters and some of the jovian and saturnian moons at resolutions approaching 1 kilometer.

Entry probes and Earth-based measurements have told us that the atmosphere of Venus contains about 90 times more matter than Earth's, and that almost 97% of it is carbon dioxide. Nitrogen contributes roughly another 2%, and the remainder consists of the noble gases argon, neon, krypton, xenon, plus water vapor, such corrosive items as hydrogen fluoride and hydrogen chloride, and some sulfur-bearing gases as well. Between 45 and 70 kilometers above the rocky surface, clouds form thick layers. Many are composed of tiny droplets of sulfuric acid produced by sunlight acting on the sulfurous gases in the atmosphere.

Prior to the arrival of the Pioneer Venus orbiter, all our knowledge of the surface came from Soviet-made landers and Earth-based radar. The Soviet spacecraft Venera 9 and Venera 10 each transmitted a panoramic image from their respective landing sites. The surface conditions are so hostile (90 atmospheres and a temperature of 733° K) that neither spacecraft functioned more than two hours after touchdown. The photographs taken show dark soil and rocks; sensors reported radioactive trace elements in the surface materials similar to those of terrestrial basaltic rocks.

The scanning radar antenna of the Pioneer Venus orbiter is the white basketlike structure on the right-hand side of the spacecraft. Photo by Hughes Aircraft Corp.

Earth-based radar has imaged only about one quarter of Venus' surface at a resolution of around 10 kilometers. Very little information exists for the remainder, even at grossly coarser resolutions. Worse still, only for a narrow band around the equator — about 1% of the surface — did accurate topographic (height) information exist.

The portions of the planet that Earth-based radar can cover are limited by a peculiar, as-yet-unexplained coincidence between the rotational period of Venus and the orbital periods of Venus and Earth. In the interval between inferior conjunctions (when Venus is closest to Earth), Venus makes exactly four complete revolutions with respect to Earth. This means that whenever Venus comes close enough to give the strongest radar echoes, we always observe the same hemisphere.

However limited the surveys, several interesting features turned up in the crude Earth-based images: two objects, named (rather prosaically) Alpha and Beta, stood out clearly. Additionally, a large ring-shaped feature was seen in the northern hemisphere — but for lack of topographic data, no one could tell whether it was a plateau or a basin. There matters stood until about two years ago.

In December of 1978 the half-ton Pioneer orbiter and entry probes arrived at Venus after a trouble-free eight month cruise from Earth. The four entry probes and carrier "bus" sampled the atmosphere and near surface conditions before they succumbed to the heat and pressure. Meanwhile, a rocket had fired to put the orbiter into a highly eccentric, 24-hour orbit. Explosive bolts blew away the covers that protected the instruments and data began to stream back across 50 million miles to NASA ground stations. Except for brief intervals when those stations had to track other spacecraft, or endure brush fires (in Australia), or earthquakes (in California), the data have arrived at the NASA Ames Research Center in Mountain View, California, in an uninterrupted flow.

Although the mission's primary goal was to investigate the venusian atmosphere and ionosphere, a novel radar mapper was part of the payload. Now, two years and 700 orbits later, planetary scientists have collected the radar results into a "first-ever" series of maps showing the continents, mountains, and valleys of our heretofore mysterious sister planet.

The radar instrument aboard the orbiter comes in two pieces — a 14" diameter antenna complete with a miniature tracking motor and an electronics package containing transmitter, receiver, and a host of microelectronics. The antenna sits on the rim of the cylindrical spacecraft, which rotates on its axis five times a minute. The tracking motor points the antenna down at the planet once each roll.

The radar performs two quite separate functions: first, it's an altimeter that measures the height of the spacecraft above the surface, and second, a mapper that detects areas of higher and lower radar brightness. The altimetric measurements are performed during that part of each 12-second roll when the antenna points toward the center of the planetary disk. The brightness mapping is done "sideways" — when the radar is looking 20° to 50° away from straight down.

Although early imaging radar systems relied on large antennae to produce a narrow beam, the Pioneer Venus instrument uses a relatively new technique called Synthetic Aperture Radar (SAR) in which antenna size has essentially no relation to resolving power (see "Alien Eyes," ASTRONOMY, January 1980). SAR relies on electronics to make precise measurements of the time and frequency spectrum of the returned radar echoes.

The parts of the echo that return first are those reflected from the surface directly beneath the spacecraft; subsequent parts come from concentric ring-shaped portions of the surface progressively farther away. Furthermore, the motion of the spacecraft relative to the planet will change the frequency of the reflected pulses. Echoes from behind the spacecraft will be Doppler-shifted to lower frequencies, those from ahead to higher frequencies.

SAR uses the delay and Doppler-shift information to break up each received radar echo into signals that have been reflected from separate locations on the surface. Because decoding the information in the returned signals is so exacting, the radar antenna contributes less to imaging resolution than do the receiver electronics — which perform an incredibly complicated analyzing job very quickly.

To help picture what happens, imagine the spacecraft is in orbit around the Earth and due to pass over the U.S. east coast at midday. At 11:35 a.m. the radar would begin taking useful altimetric measurements over Scandinavia as the spacecraft dropped below the predetermined altitude of 4700 kilometers. Each measurement would determine the average distance to, and brightness of, a patch of ground below. As the altitude decreases, so does the diameter of the spot the radar looks at: beginning with a diameter of 50 kilometers, the spot shrinks to 10 kilometers at closest approach.

By 11:54 a.m. the spacecraft would be passing over New England at 700 kilometers altitude and the side-looking mode would engage automatically. Each 12-second roll would produce radar brightness readings for up to sixty-four 40 km x 40 km surface "elements" on either side of the orbital path. This rather fuzzy resolution would steadily improve as the altitude decreased.

The closest approach to Earth would occur over Mexico and the entire process would continue, resolution coarsening in reverse order, until the spacecraft rose above the 4700 kilometer limit at 65° south latitude, off the Pacific coast of South America.

Substitute the place names and that's the Venus orbiter's daily routine. Because Venus takes 243 Earth days to rotate once on its axis, the ground track of each 24-hour orbit advances around the planet at a rate of about 1.5° of longitude per day. After the first 243 revolutions, scientists altered its orbit to interleave the next 243 tracks with the original ones. In this way, the orbiter spun a dense net of altimetric and radar brightness measurements between the limits of 74° N and 63° S latitude — almost 93% of Venus' surface.

Over the last year and a half, researchers at MIT under Gordon Pettengill have carefully collected and studied the radar readings. Using data supplied by NASA's Ames Research Center, they transformed the measured radar altitudes into corresponding values of Venus-radii. Since changes in the venusian radius are caused by mountains, valleys, craters, continents, and so on, the scientists built up a relatively detailed topographic map.

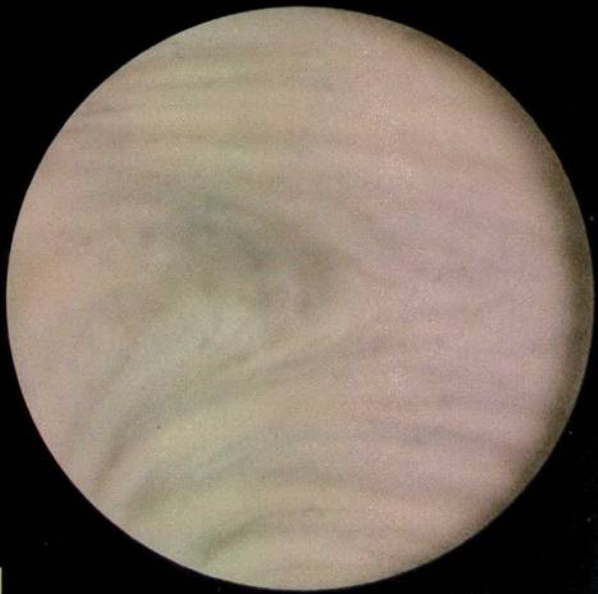
Analysis of the altimeter echoes also gives a measure of the surface roughness on a scale somewhat larger than the wavelength of the signals — in this case 17 centimeters. The side-looking imaging radar, in common with Earth-based experiments, also measures the surface roughness, but on a smaller scale — 5 to 15 centimeters, depending on the look-angle. The altimeter data also yield information on the electric properties of the surface, which can help distinguish between broad classes of geological materials, such as basaltic rock, granitic rock, or sand.

Perhaps the most exciting results have come from the altimetric measurements. For the first time, we have been able to peer through the clouds at the mountains and valleys of our sister planet, and there's plenty to see. In the far north, a high plateau, Lakshmi Planum, rises 2 kilometers above the surrounding plain. Larger than Tibet, the plateau — first seen by Earth-based radar experiments — was originally thought to be a basin. Pioneer's radar shows it not only to be elevated but ringed by tall mountain ranges. The largest of these, Maxwell, rises to a full height of 10.8 kilometers above the plain.

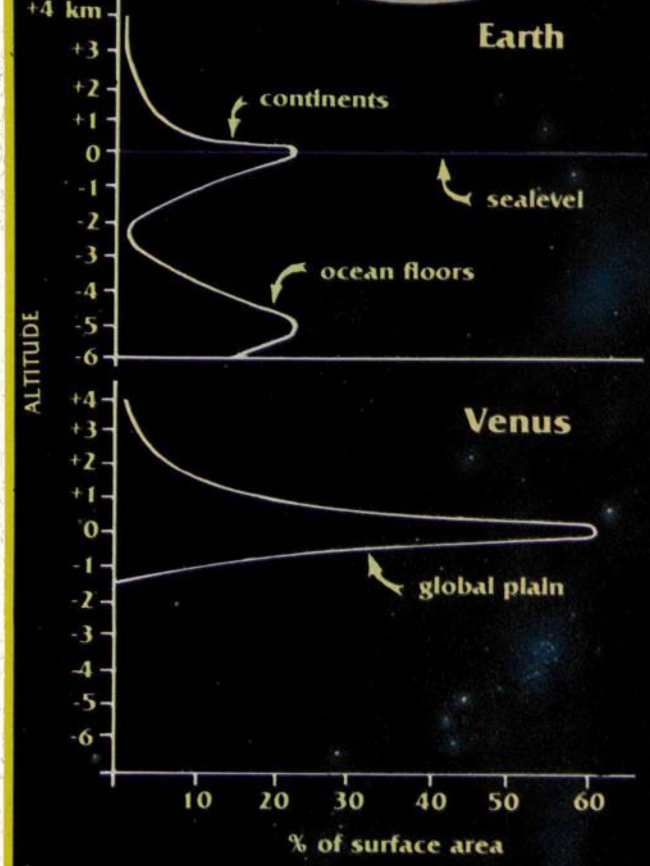
The vast northern structure including Lakshmi and its mountains makes up an entire continent recently named Ishtar Terra by the nomenclature committee of the International Astronomical Union. (They have decided to reserve exclusively to Venus the names of classical goddesses and famous women in Earth's history.)

To the south and east of Ishtar lie vast depressions. If Venus were colder and had abundant

The "Twin" Planets?



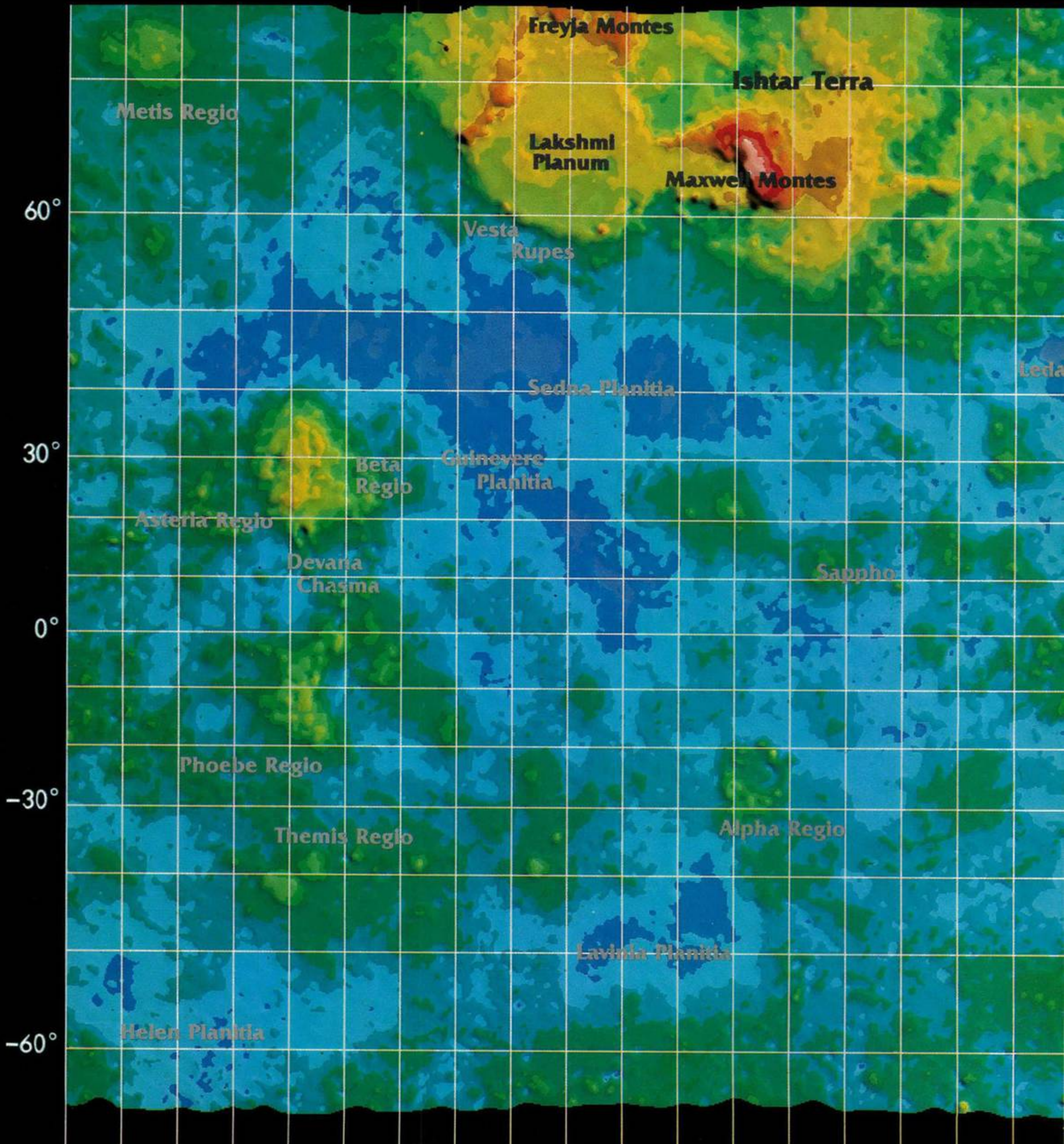
	EARTH	VENUS
Diameter	12,756 km	12, 103 km
Mass	5.98 x 10^{27} grams	4.87 x 10^{27} grams
Density	5.52 grams/cm^3	5.11 grams/cm^3
Rotation	1 day, direct	243 days, retrograde
Composition	Nickel, iron core, basaltic mantle, silicate crust	?
Atmosphere	77% nitrogen 21% oxygen 1% water vapor	97% carbon dioxide 3% nitrogen
Surface Pressure	1 bar	90 bars
Clouds	water vapor	sulfuric acid
Surface Temperature	287° K	733° K
Surface Gravity	1.00	0.88
Surface Materials	water/silicate rock	?
Magnetic Field	0.6 gauss dipole	none



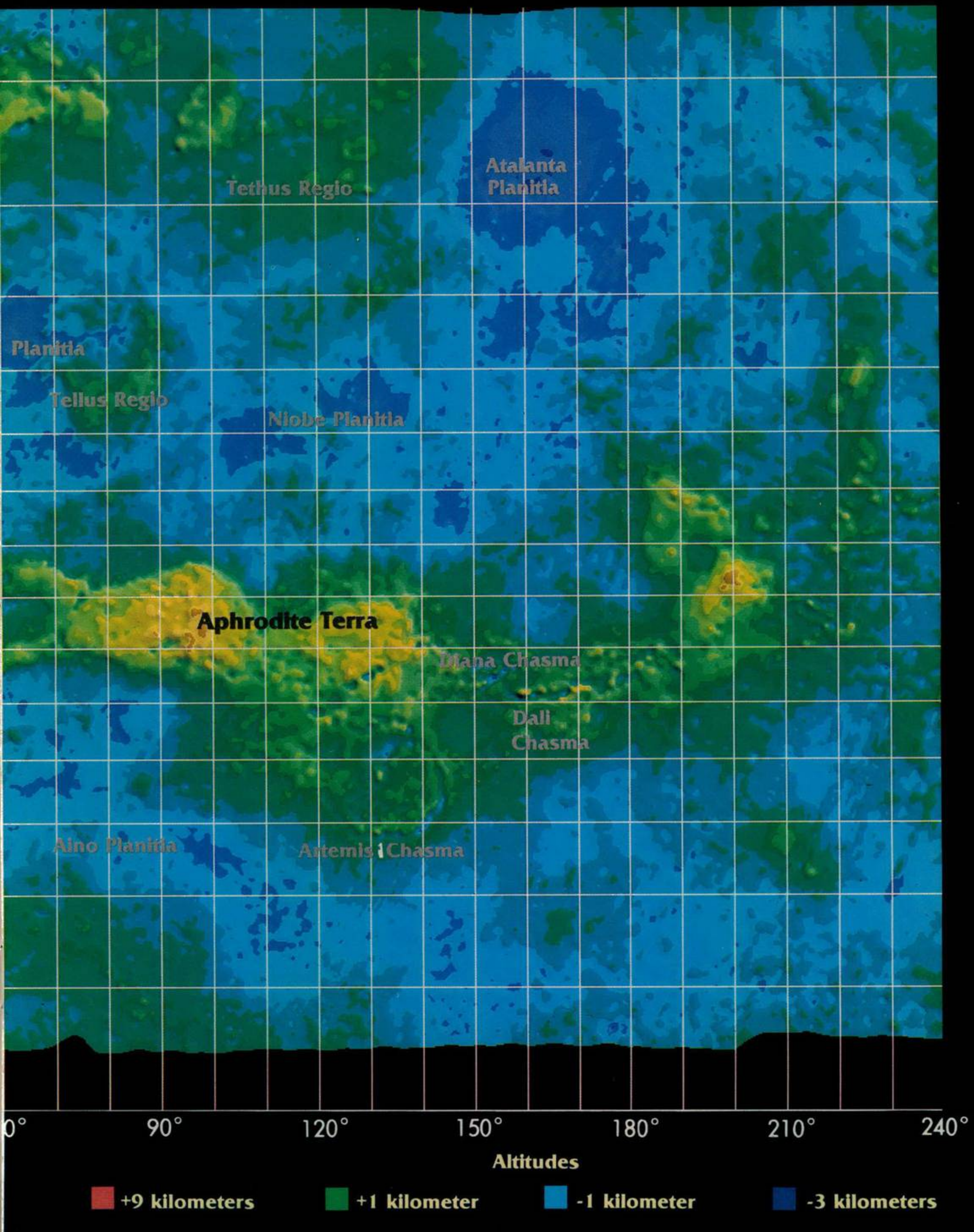
The topography of Earth clusters mainly at two altitudes: the continents at sealevel and the ocean floor 5 km below. On the other hand, most of Venus' surface lies on a global plain close to its "sealevel" (a planetary radius of 6051.4 km).

painting by Victor Costanzo

The Physiography of Venus

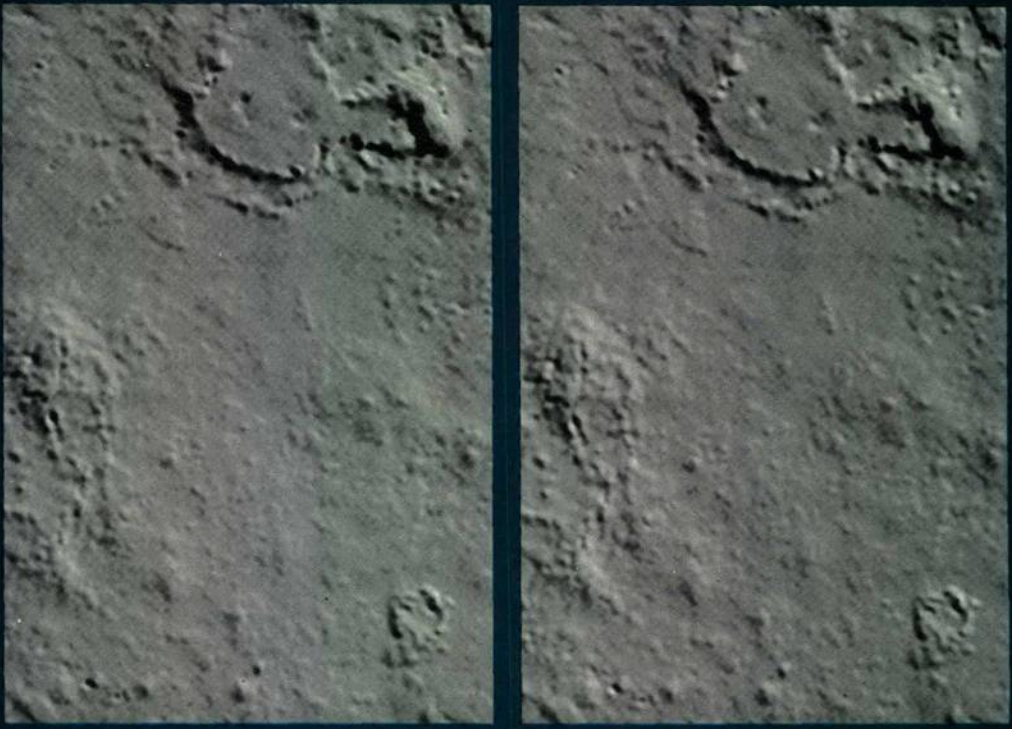

Freyja Montes
Ishtar Terra
Metis Regio
Lakshmi Planum
Maxwell Montes
Vesta Rupes
Leda
Sedna Planitia
Beta Regio
Guinevere Planitia
Asteria Regio
Devana Chasma
Sappho
Phoebe Regio
Themis Regio
Alpha Regio
Lavinia Planitia
Helen Planitia
60°
30°
0°
−30°
−60°
−70°
240°
270°
300°
330°
0°
30°
6
±65°
±30°
0°
0
1000
5000
KILOMETERS

("sealevel" on Venus corresponds
to a planetary radius of 6051.4 kilometers)



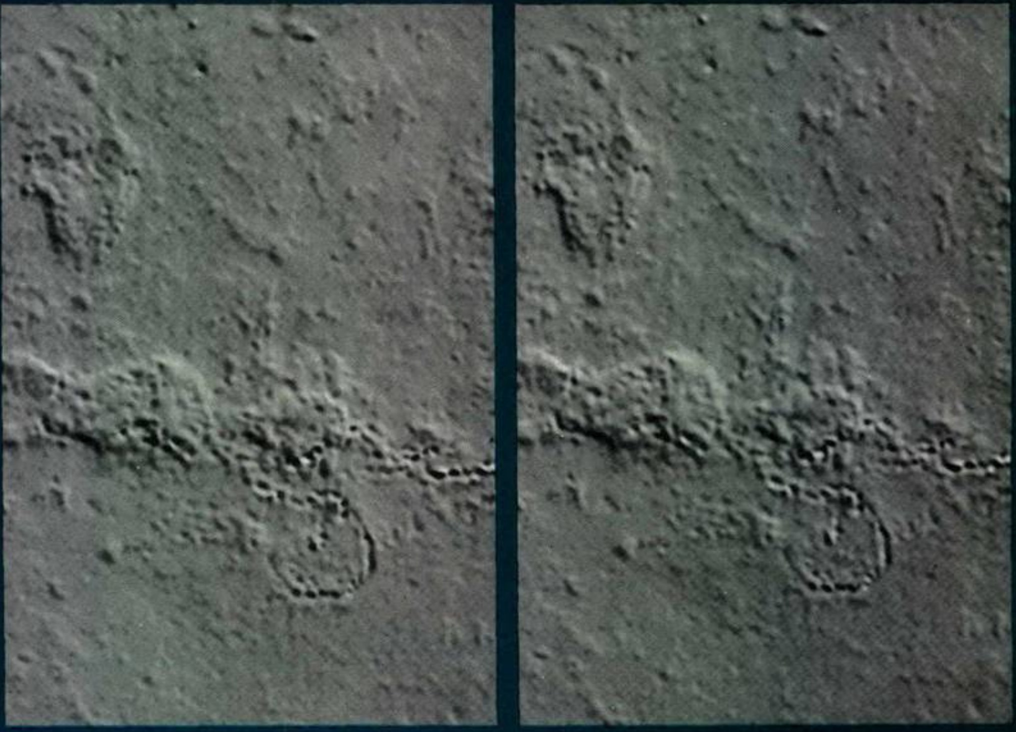
Tethus Regio
Atalanta Planitia
Planitia
Tellus Regio
Niobe Planitia
Aphrodite Terra
Diana Chasma
Dali Chasma
Aino Planitia
Artemis Chasma
0°
90°
120°
150°
180°
210°
240°
Altitudes
🟥 +9 kilometers
🟩 +1 kilometer
🟦 -1 kilometer
🟦 -3 kilometers

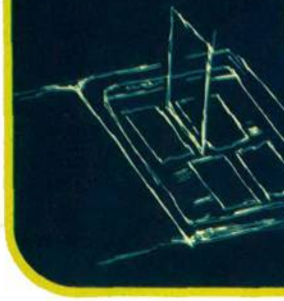
Peaks, Plains, and Chasms



Ishtar Terra (top center) and Beta Regio (left center) rise high above the intervening plains of Sedna and Guinevere. The tallest peak on Venus is Maxwell, top right.

The southern and eastern parts of Aphrodite Terra (across center) are carved by the chasms of Artemis, Dali, and Diana. Niobe Planitia lies at top center.





To see Venus' relief in stereo, hold a piece of cardboard upright between the two paired images. Illuminate both photos equally. Look down, each eye on one side of the cardboard, and fuse the two images into one. The topography may abruptly pop out. Photos by NASA/*USGS/MIT*.

surface water, these would be broad, shallow oceans. We see no evidence of the deep trenches that crisscross Earth's ocean floors, although two areas with valleys are reminiscent of the great terrestrial rift zones. One lies within the feature named Aphrodite Terra, a continent the size of Africa, just south of the equator. At the eastern end of this continent, at 20° S latitude and 160° E longitude, several long valleys enclosed by high mountains wind across the surface. Some of the valleys are over 2 kilometers deep and hundreds of kilometers long.

To the southwest of Ishtar lies the mountainous region named Beta, dominated by two high peaks, Rhea and Theia, that may be volcanic in origin. The whole area is scored with deep valleys and long strips of rougher surface. On one point all geologists agree: Beta, Ishtar, and Aphrodite are highly complex features. With no surface water or high winds, erosion on Venus must proceed very slowly. We can expect the results of different geological processes, operating perhaps many hundreds of millions of years apart, to overlap and intermingle.

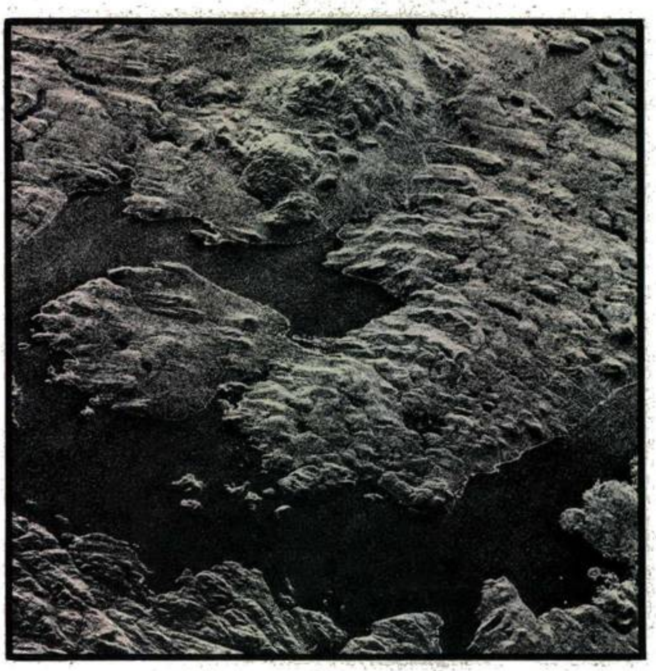
Although the complexity makes geological interpretation very difficult, it's actually a blessing in disguise. Preserved in the venusian crust lies evidence of an epoch of geological history that began long after the Moon and Mercury had become geologically dead — an epoch whose earthly remains have largely been obliterated by the ravages of erosion and continental drift.

Large, deep craters, so common on the Moon, Mercury, and (to a lesser extent) Mars, are conspicuously absent. Although the lowlands contain many circular features, few are more than 200 meters deep. The highlands contain several deep craters, but none with diameters exceeding 160 kilometers. One simple explanation favored by many geologists is that the highland areas are relatively young, and accordingly have sustained fewer impacts from asteroids and comets. In this theory, some other process gradually filled in the lowland craters. Likely candidates include chemical weathering, lava flows, and "surface relaxation" — a catch-all term for processes scarcely understood as yet.

We know little so far about the composition of venusian rocks. The Russian Venera 9 and 10 probes that landed on the eastern foothills of Beta measured surface radioactivity in their immediate vicinity that most nearly resembles basalt, a volcanic rock. The Pioneer Venus radar shows Beta to have a high dielectric constant, also a possible indicator of volcanism. But to draw more definitive conclusions, planetary scientists will have to make detailed studies of the radar data for years to come.

Having performed all the tasks expected of it, the radar instrument aboard the Pioneer orbiter will be turned off around the middle of this month. Many other instruments, however, may continue to function for several years while the Sun's gravity slowly perturbs the spacecraft's orbit. This alteration will take the instruments into regions where scientists can better study the interaction of the solar wind with the venusian ionosphere.

Although the radar mapper has increased our knowledge of Venus' topography far beyond what could be deduced from Earth, many questions still tantalize. Why are the craters and basins so shallow? Why is Maxwell so much higher than the other mountains? Do venusian continents drift about as do those on Earth? What processes have formed the mighty rift valleys associated with Aphrodite and Beta?



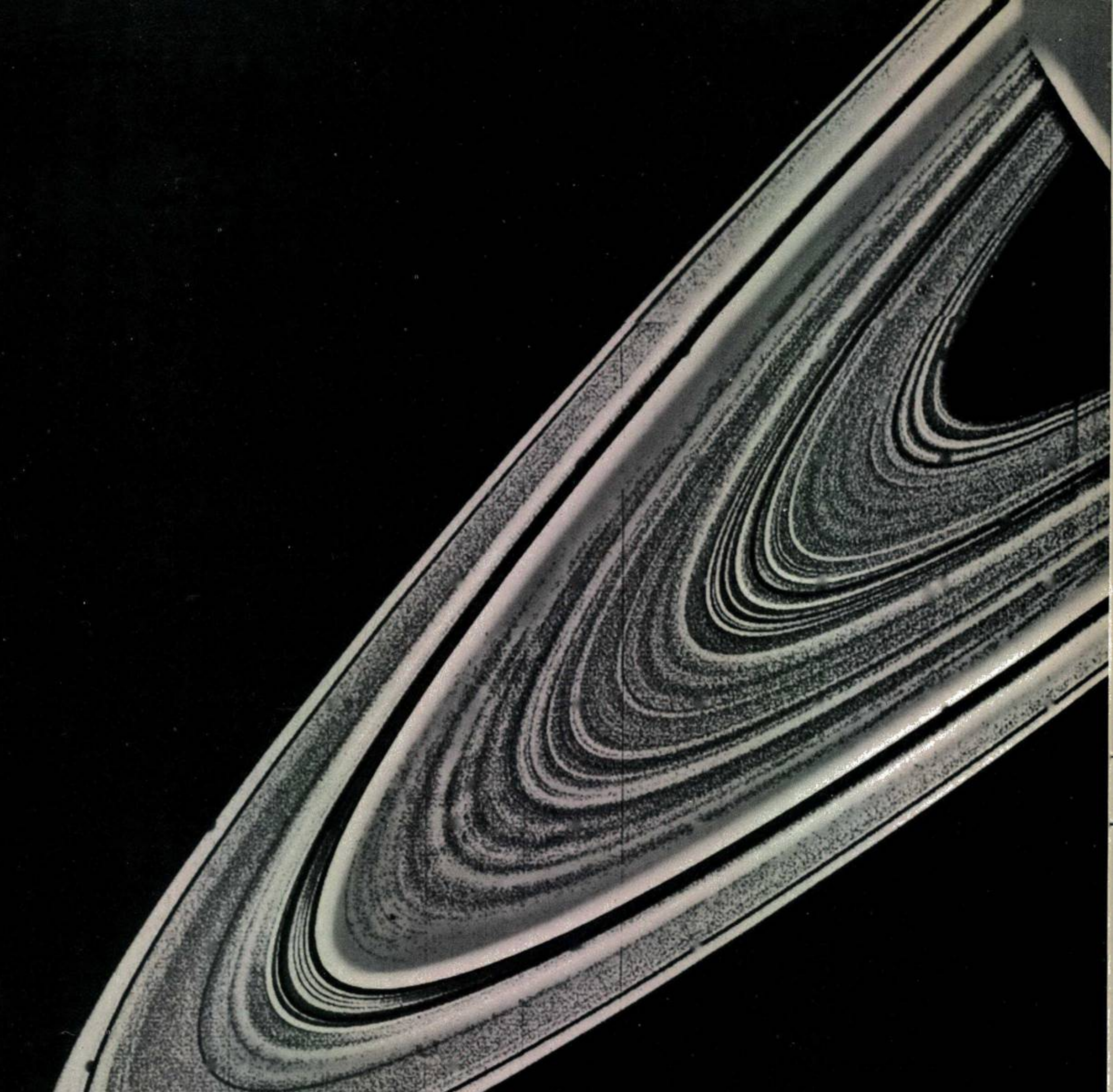
The scanning radar that the VOIR mission will use to survey Venus will provide images as clear as this of the flooded ancient impact crater at Manicouagan, Quebec. NASA photo.

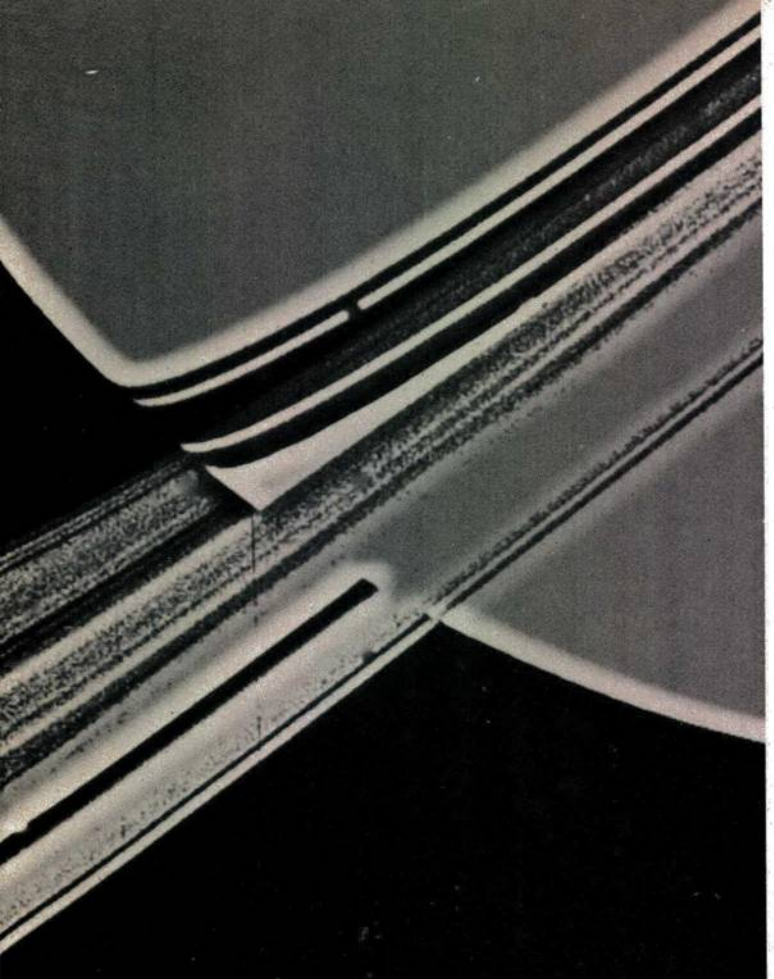
We aren't likely to answer these questions for many years yet, but already plans are afoot to launch another orbiting radar to take up where Pioneer left off. Named the Venus Orbiting Imaging Radar (VOIR), it could be launched from the Space Shuttle as early as 1986. Present NASA plans call for VOIR to commence its study of Venus from an elliptical orbit which engineers will gradually circularize by dipping the craft into the fringes of the venusian atmosphere — a technique called aero-braking.

After a month or more of this, the spacecraft should be following a circular, nearly polar orbit at an altitude of 200 kilometers. From that vantage point, its radar system would make contiguous SAR scans of the surface, telemetering the data back to Earth for four months or more. The result would be a series of detailed maps of the entire planet providing geologists and geophysicists with an unparalleled wealth of information on our sister planet.

So clear will be the images from VOIR's radar that they will equal or surpass all previous orbital spacecraft imagery — both in resolution and contrast. Carrying off this mission successfully will greatly enhance not only our understanding of mankind's nearest planetary neighbor, but also — by comparison — our understanding of the home planet, Earth.

Stewart Nozette is a graduate research assistant at MIT and a Ph.D candidate. His main interest is in exploring the solar system with unmanned spacecraft. Peter Ford is a member of the MIT research staff, and is in charge of data analysis done by the Pioneer Venus orbiting radar group.

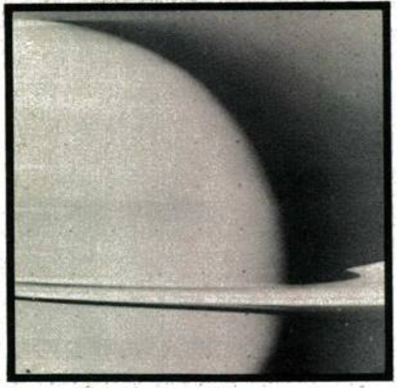




More Science from Saturn

by Richard Berry

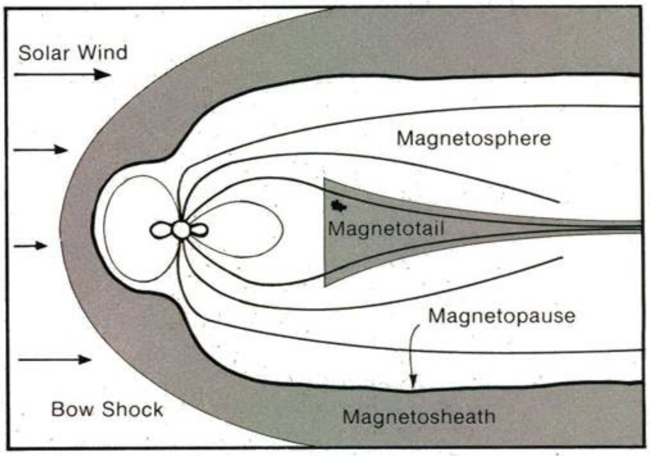
FIELDS



Two days before encounter, Voyager approaches the ring plane of Saturn.

The study of magnetic fields and the interactions between the magnetic field and the solar wind was the principal task of Pioneer 11. Voyager, though largely a camera-oriented mission, also carried sophisticated instruments for measuring particles, fields, and radio waves in space. At Saturn, Voyager continued the exploration that Pioneer had started.

A vast invisible structure, the magnetosphere, surrounds a planet that has a magnetic field. It consists of atomic particles and ions (atoms stripped of one or more electrons) circling the lines of magnetic force, and carried along by the magnetic field as the planet rotates. Left to itself, the magnetic field would simply extend in all directions forever. However, it cannot: the magnetosphere must interact with the gusty fast-moving outflow of atoms and ions from the Sun called the solar wind. Solar wind particles exert a pressure on the magnetosphere, pushing it away from the Sun and forcing it to stream out behind the planet like the tail of a comet.



The strength of the solar wind varies, sometimes quite rapidly, so the magnetosphere bounces in and out. As Voyager approached Saturn, the first indication that the spacecraft was nearing Saturn's magnetic realm came from ions bouncing off the bow shock where the solar wind abruptly rams into particles deflected by the magnetic field. Then, at a distance of 26.2 Saturn radii, the spacecraft crossed the bow shock for the first time, passing into the turbulent magnetosheath. At 23.7 Saturn radii, the

Computer-enhanced, Saturn's B and C rings display a complex structure. NASA photo P-23068 taken November 6, from 8,000,000 km.

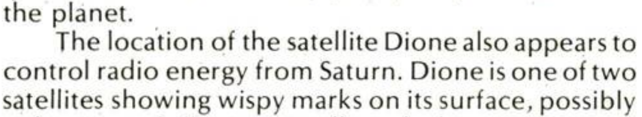
craft suddenly passed into the quiet magnetospheric regime of Saturn, then out of it, then into it again, and out again, as the tortured magnetopause moved rapidly toward and away from Saturn. Finally, at 22.9 Saturn radii, Voyager passed into the magnetosphere to stay.

RADIO SCIENCE

On the day after encounter, Saturn appears as a crescent to Voyager's cameras.

As Voyager approached Saturn, it measured the rotation period of the planet to high precision (10h 39m 24s) by timing radio emissions. However, the source of the radio emission amounting to 20 billion watts of radio power remained a mystery. Planetary radio emission is usually connected to the planet's magnetic field, and, from Pioneer 11 data, Saturn's seemed to be too well-behaved to emit variable radio signals. While 1000 times stronger than Earth's field, it is only 5% as strong as Jupiter's magnetic field and is quite accurately aligned with its rotational axis — to better than 1° in fact — compared to the substantial 10° tilts of the Earth, the Sun, and Jupiter fields.

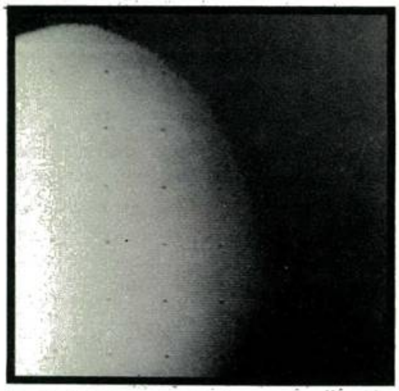
From its variability, the radio source was apparently confined to a region of Saturn near 90° longitude. As Voyager flew down toward Saturn's southern latitudes, the main peak faded out. This placed the source at high northern latitudes, probably resulting from particles trapped in an irregularity, or "anomaly," in the magnetic field. Such an anomaly might be produced by irregularities in the flow of conducting material (liquid metallic hydrogen in the case of Saturn and Jupiter) deep in the core of the planet.


JUPITER
Trapped Atomic Particles
SATURN
Magnetic Field Tilted 11° to Rotation Axis
Magnetic Field Aligned with Rotation Axis

The location of the satellite Dione also appears to control radio energy from Saturn. Dione is one of two satellites showing wispy marks on its surface, possibly indicative of "outgassing," and there is a peak (discovered by Pioneer 11) in the number of magnetospheric particles at Dione's orbit. While the mechanism is not understood, Jupiter's satellite Io controls some of the jovian radio emissions — almost like a switch — so there may be a similarity. If Dione does "outgas" materials (i.e., plumes of steam or other gases, for example), these could trigger the generation of radio waves.

As it raced past and then away from Saturn, Voyager turned its instruments on the the vast dark shadowside bulk of the planet in search of aurorae and lightning flashes. The ultraviolet spectrometer found a superb auroral zone some 9000 kilometers across centered on the pole. Saturn's aurora is less like Jupiter's, which is driven by ions spiraling down magnetic field lines from the Io torus and not centered on the pole, and more like Earth's aurora, with electrons streaming down to excite atoms and molecules in the atmosphere. Voyager also detected "whistlers" from lightning strokes, so it appears that Saturn, like Jupiter, has lightning in its clouds.

TITAN

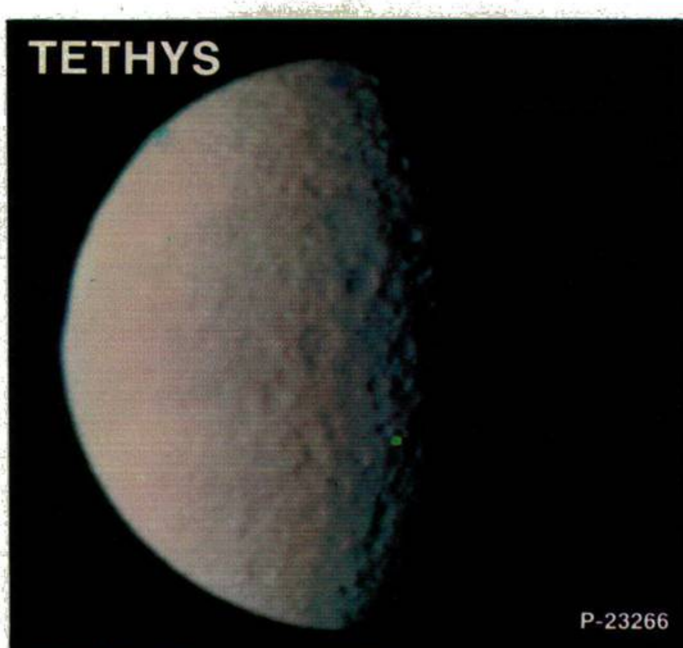


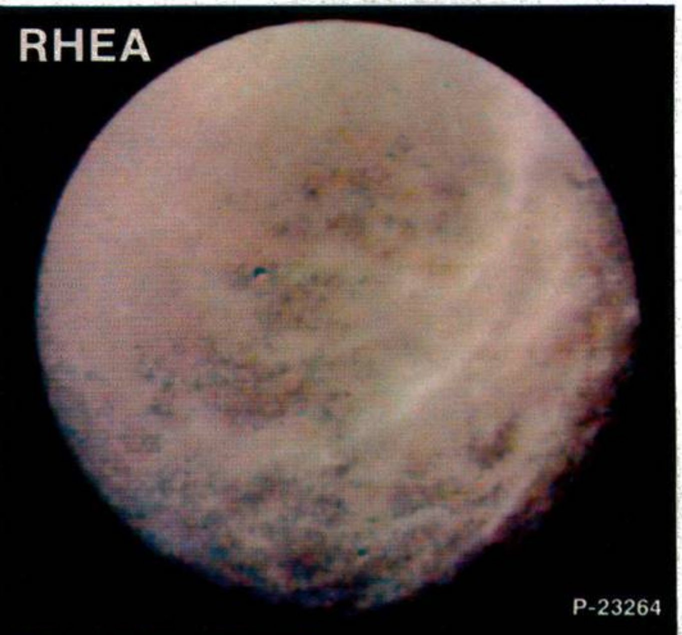
Titan's appearance is remarkably bland. Its atmospheric haze extends hundreds of kilometers.

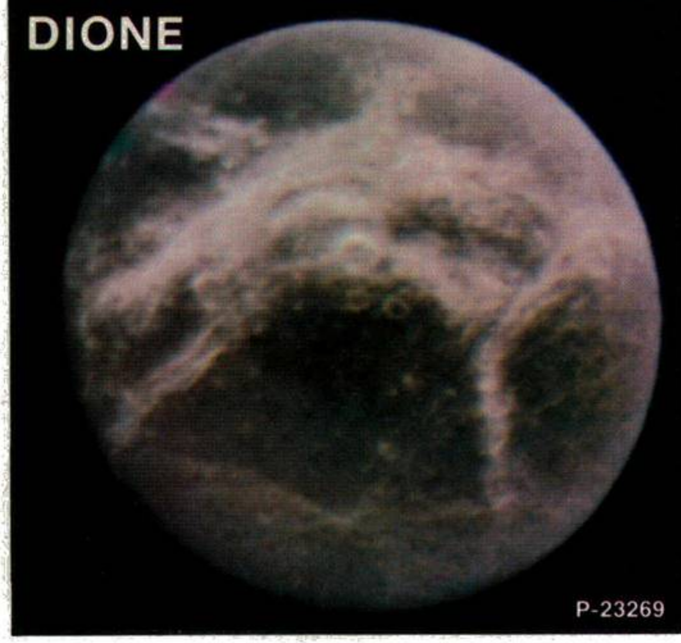
When Pioneer 11 flew by Saturn, the magnetosphere was smaller, more compressed by a powerful solar wind, than it was when Voyager flew by. Titan lay outside the magnetosphere, exposed to the solar wind. If Pioneer had attempted the same measurements that Voyager did, it would have failed: in the turbulence of the solar wind, the subtle plasma interaction with Titan would have been buried in the noise. At 20.3 Saturn radii, when Voyager flew by Titan, it was deep inside the quiet magnetic field of Saturn, and the important observations of Titan's interaction with magnetic fields were possible.

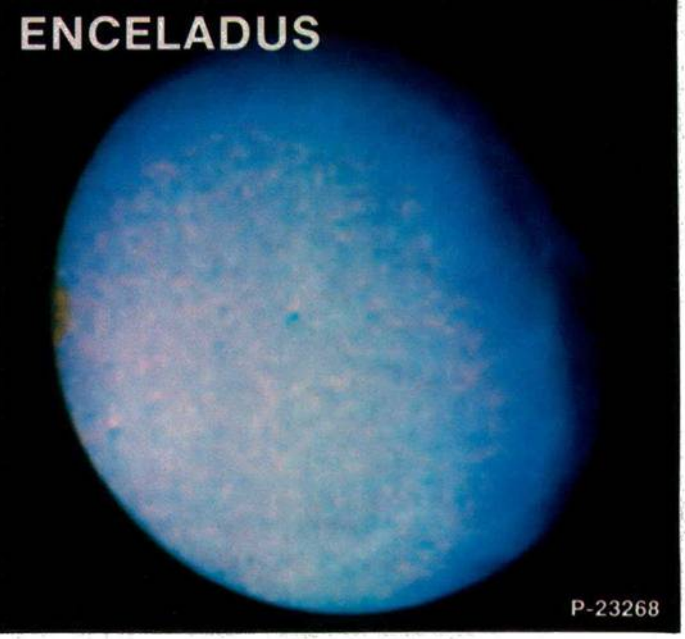
Although Titan does not have an appreciable magnetic field of its own, it does have a strong effect on the plasma that streams by it. The plasma's speed of flow drops abruptly, and the particle density increases. It generates a magnetic field, which in turn induces a voltage across Titan, and that an electric current flowing around Titan. On the backside of Titan, electrostatic oscillations generate radio signals around 50 kilohertz frequency that radiate about 20 kilowatts of power. This mechanism for generating radio waves is similar to the way they are generated in a radio antenna.

Titan's atmosphere is composed mainly of nitrogen with a very important 1% to 10% methane component. Traces of ethane, ethylene, acetylene, and hydrogen cyanide also attest to chemical reactions driven by ultraviolet light. Methane molecules, broken into fragments, recombine with other methane fragments, heavier hydrocarbon molecules, and the ionized remnants of nitrogen

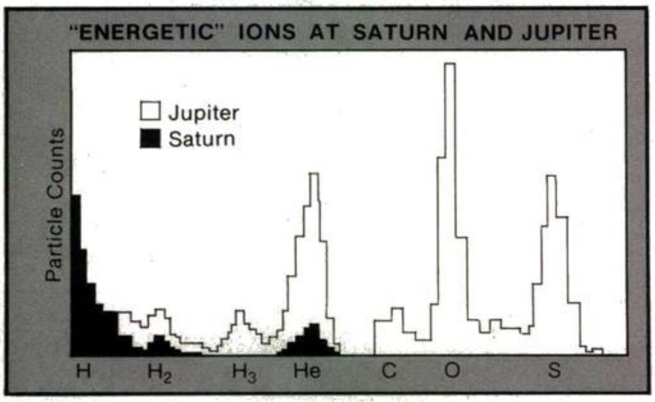

TETHYS


RHEA


DIONE

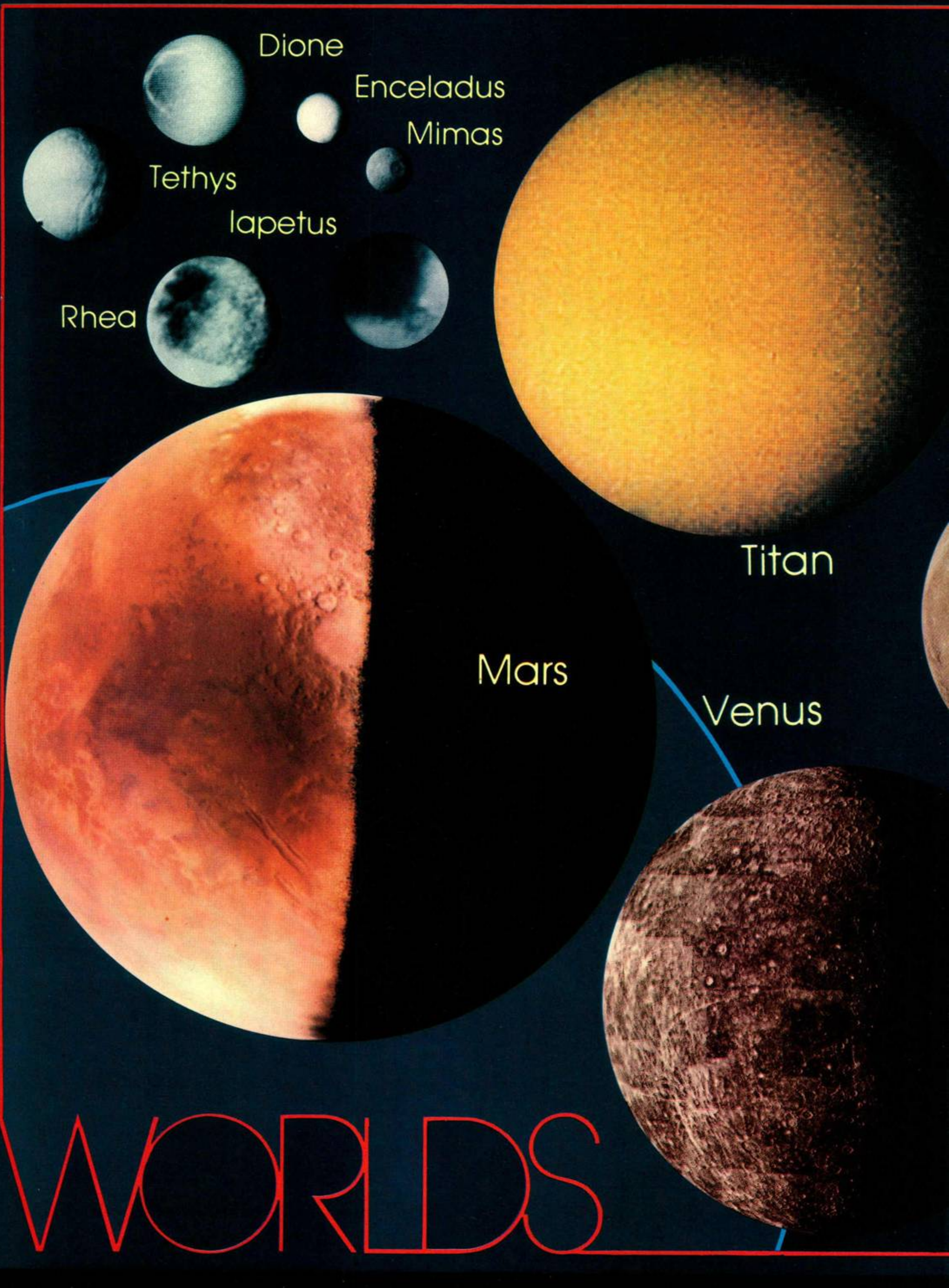

ENCELADUS

molecules to form complex and colorful polymers and minute particles of smog. Hydrogen, a byproduct of these reactions, is too light a molecule for Titan's gravity to retain, so it escapes into space.

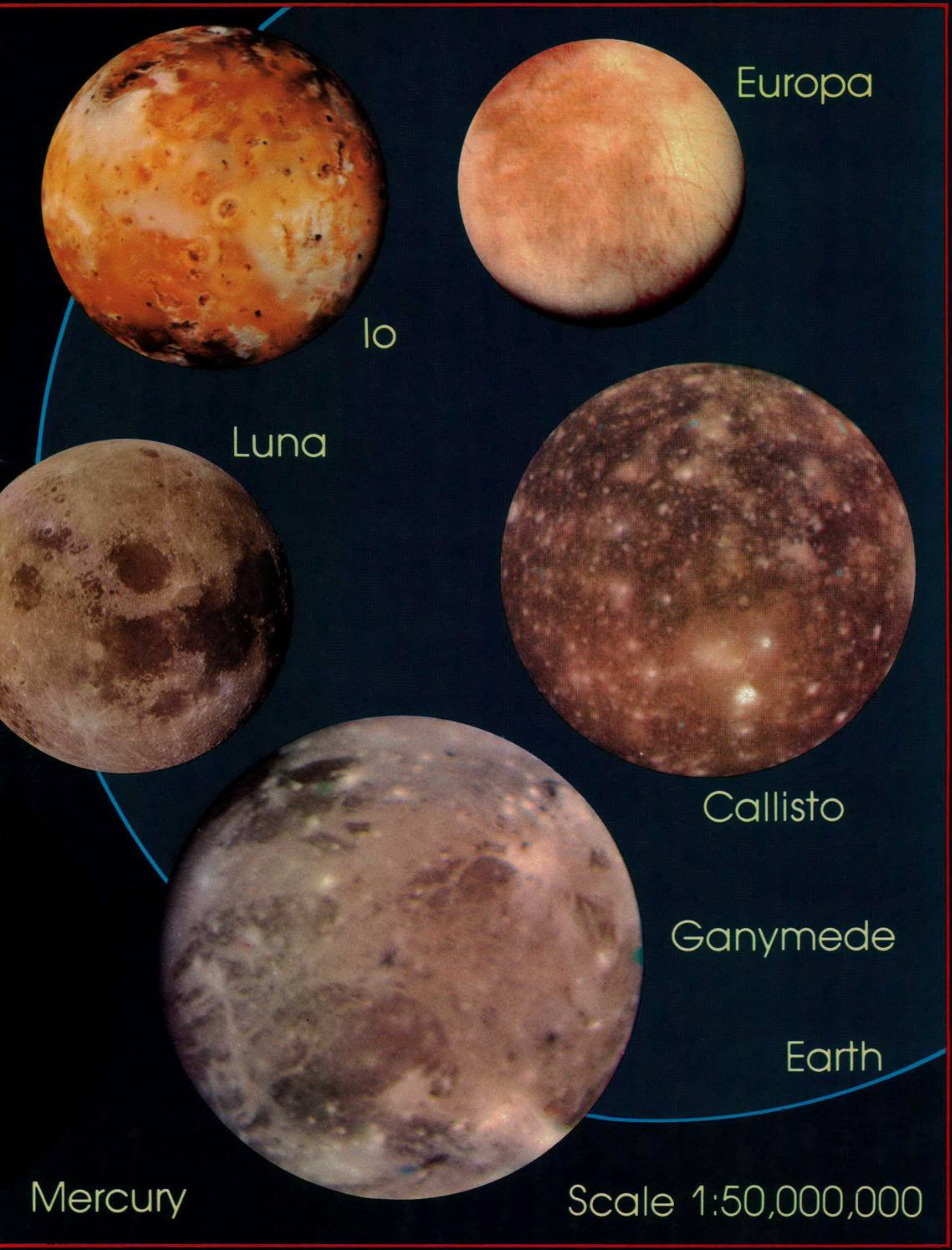

"ENERGETIC" IONS AT SATURN AND JUPITER

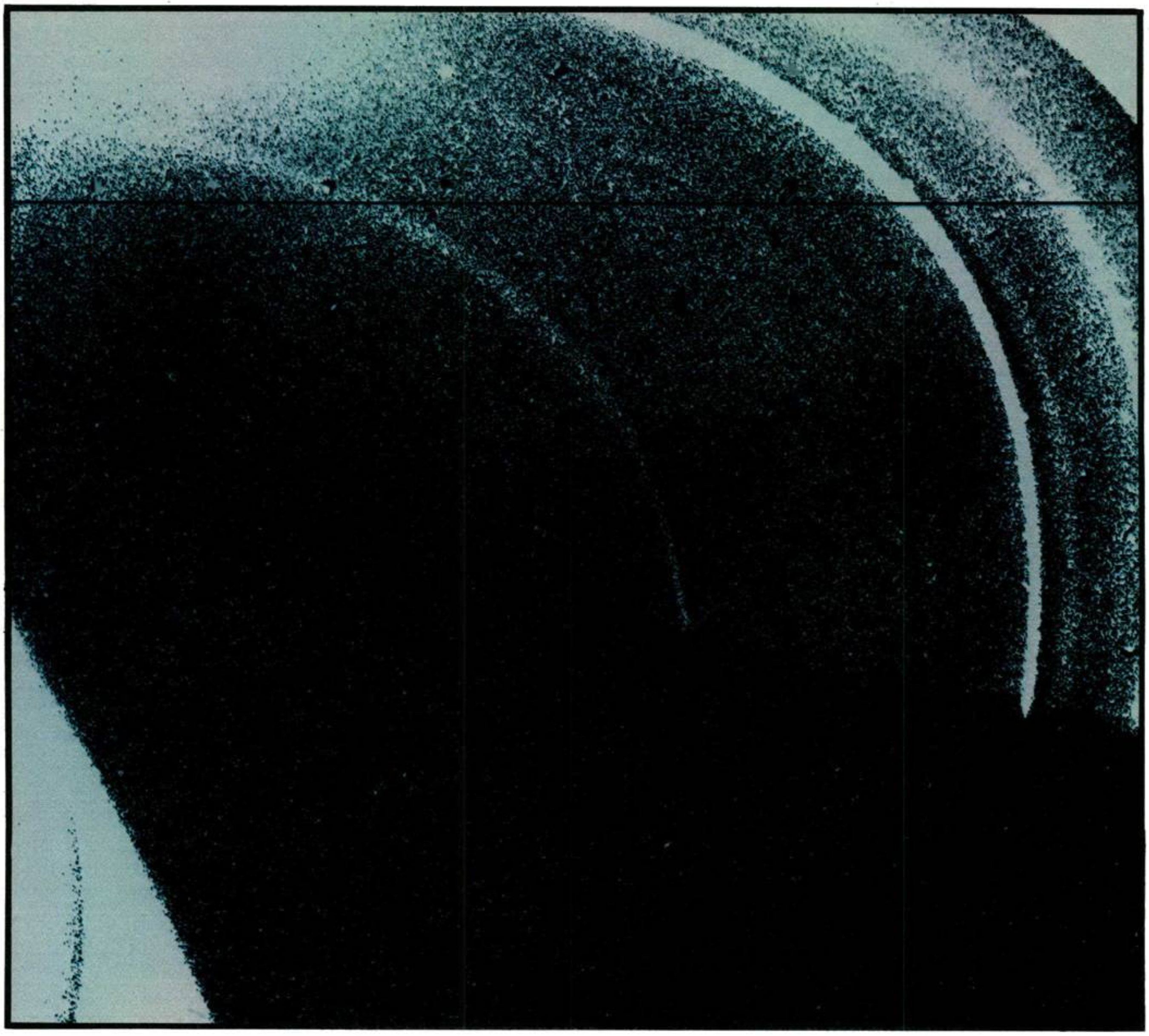
Before the radio occultation data were fully analyzed, the diameter of Titan remained uncertain. It has now been measured: Titan is 5120 kilometers in diameter, and its average density is 1.92 grams per cubic centimeter — virtually the same as Jupiter's slightly larger moon, Ganymede. The atmospheric pressure at the surface is 1.5 bars (1.5 times Earth's surface pressure), and the gases there have a density five times greater than Earth's also largely nitrogen atmosphere.

Titan's atmosphere has evolved, but in a radically different manner than Earth's, Mars', or Venus' atmospheres. The solar nebula constituents of an Earthlike planet are all present — Titan retained its oxygen as water, its carbon as methane, its nitrogen as ammonia. From an atmosphere perhaps initially much denser, the hydrogen, a gas too light to be held by Titan's gravity, escaped; the water froze out; the ammonia (NH_3), under the action of sunlight, became nitrogen and hydrogen which escaped; and the methane is being slowly converted into hydrocarbons and collecting on the cold surface of the planet. Methane and nitrogen are light enough to


Dione
Enceladus
Mimas
Tethys
Iapetus
Rhea
Titan
Mars
Venus

WORLDS

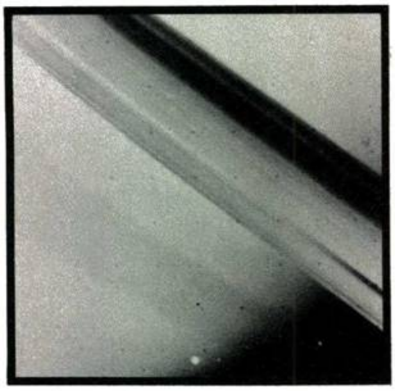

Europa
Io
Luna
Callisto
Ganymede
Earth
Mercury
Scale 1:50,000,000



Taken from 250,000 km, this November 13 photo shows the D ring extending from the edge of the C ring halfway to Saturn. NASA photo P-23262.

remain gases at Titan's temperatures, but heavy enough not to be lost into space.

TITAN'S TORUS



Interesting contrast reversals occur where Saturn's rings cross the terminator.

Aside from driving the evolution of the atmosphere, the loss of hydrogen from Titan has another important consequence: Saturn is encircled by a ring, or torus, of hydrogen that has escaped from Titan. The torus extends beyond Titan's orbit some 300,000 km and inward to Rhea's orbit. Unlike Jupiter's Io torus, the Titan neutral (i.e., non-ionized) hydrogen torus observed by Voyager is lightweight (25,000 tons total mass), cool, and thin. Titan's loss of hydrogen to the torus only amounts to a kilogram per second, but such a loss can be important over the age of the solar system.

A hydrogen atom or molecule in the torus is eventually ionized and swept up by the rotating magnetic field of the planet. The hydrogen then becomes part of the hot ionized gas of the magnetosphere. Voyager measured the constituents of Saturn's magnetosphere and found a markedly different particle environment than Jupiter's. Whereas Jupiter's magnetosphere is filled with oxygen, sulfur, sodium, and potassium from Io's volcanos, Saturn's magnetosphere lacks these exotic components.

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ASTRONOMY FORUM

Astronomers Meet in Tucson

The noise of the trucks on Interstate 10 woke me on the first day of the conference. Already the hills to the east were bathed in ruddy early morning Arizona sunlight, and various species of cactus grew in the parking lot outside. Here, in Tucson in mid-October, astronomers from the Division of Planetary Science of the American Astronomical Society (DPS/AAS) were meeting for four days to present scientific papers, hear the latest findings from other workers in their field, and discuss new ideas with their colleagues.

The scientific sessions began a bit late due to a malfunctioning PA system and a blown bulb in a slide projector. To squeeze the hundreds of papers into a four day meeting, each speaker had just five minutes to present his findings and another five to conduct a question and answer period. The result, perfectly predictable, was that nearly everyone ran overtime. Imagine a speaker trying to present a year of research in a ten-minute timespan — the topic: Does Ganymede show evidence of plate tectonics? If the speaker can speak quickly enough, she'll present her entire case in full. The slides? Beautiful. What a surface, what a network of grooves and faults and ripped-up craters — BZZTT!!! — and the time is up.

Scientific sessions have a rhythm of their own. Each morning they begin with coffee, gooey donuts, and, by 10 a.m., the sounds of the audience shuffling through notes. The papers are a rich smorgasbord of scientific data: comprehensive reviews of Mars and the jovian atmosphere, a movie of Jupiter's plumes and barges, calculations of colliding vortices, vivid multispectral classification maps, new data on the rotation of Neptune — and on and on.

Some papers impressed the listening scientists. Some didn't.

"Do you believe his conclusions?" I heard one scientist ask another.

"No," said the other, "but his methodology is excellent."

Almost as if to underscore the fluid nature of scientific thought, the asteroid session hinged on what several years ago had seemed like a rather nutty idea — the notion that some asteroids are binary or multiple. That *hypothesis* is now supported by a growing body of observational and theoretical evidence. Theoreticians have no trouble fragmenting asteroids; "the problem," said Clark Chapman, an asteroid specialist, "is whether [asteriods] can become binary before they're entirely destroyed."

> **"I want our society to keep in touch with developments in the galaxies...because that's where we ought to be."**
>
> James Michener

Because of the sheer number of papers presented, many sessions ran in parallel — much to the distress of those wanting to hear particular papers in two concurrent sessions. Throughout there were comings and goings, grumblings, and moans that an important paper had just concluded....

High on the list of priorities is the annual "NASA Night." Tonight, Bruce Murray, director of the Jet Propulsion Lab, and NASA's Geoff Briggs will tell the assembled scientists what the future holds in planetary exploration.

"We are in a crisis," proclaims Bruce Murray; "after Voyager 2 flies by Saturn, there will be at least 4½ years without a mission." By comparison, there have never before been 12 months without the exploration of an alien surface since our space program began. He traces NASA's woes to a large number of causes, some political, some economic, some internal. "The initial dynamics of our system are running down, and we must seek a renewal," he says.

In the political arena, a diminishing U.S.-Soviet rivalry, congressional reforms, Presidential malfeasance, the lack of a serious space lobby group, and the devastating cost and loss of American pride due to the Vietnam War, all contributed to a weakened space program. NASA's own lack of long-term goals also helped cripple it.

"The Shuttle," says Murray, "has created a launch vehicle capability problem." Vehicle failures have occurred before, but with the Shuttle there is no back-up — production of the Titan-Centaur rocket was dropped. Not much can fly until the Shuttle works, but on programs like Galileo, "we're now talking '86 with an '88 back-up — we're marching backward!"

Furthermore, according to Murray, the industrial base of the United States is not adequate for government's requirements today. The growing commercial and military uses for space have outraced the "institutional base" of space technology. One problem is "Can we find people who can do the work?" Another is keeping them together: "It's not obvious how you can *hold* the team of people — scientists, sophisticated engineering talent, public officials — people who

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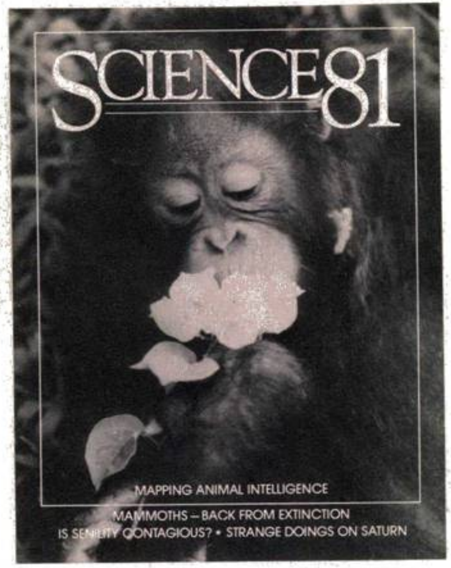
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believe in space science." The American space team is scattering — to other jobs, to other research, to fields with brighter futures.

Geoff Briggs, the Deputy Director of NASA's Planetary Division, reviews the highlights of the space program, praising the Viking orbiter which gave up after four years (remarkable considering its design life of 90 days), Pioneer Venus, and Voyager (about to reach Saturn then). He describes the Mars Data Analysis Program, an effort to use the backlog of data from the Viking program. The Jupiter orbiter mission, Galileo, has been difficult: "Our one development program of the last 18 months has been sheer bedlam. Our 1982 launch has slipped to 1984, with the two spacecraft scheduled to arrive in '86 and '87 for a 20-month, 11-satellite tour of the jovian system [instead of the single launch originally planned]. The orbiter and probe will launch separately, and we'll use a powered slingshot past Mars to supply the extra energy." Despite problems with the cameras and the electronics, Briggs says, "Galileo is 'under control' is how I would put it."

"We have a mission, but it does not outprioritize the VOIR mission."
Geoff Briggs

The 65,000-pound payload capability required to lift Galileo is the driving impulse behind the Shuttle. Speaking of the Shuttle, Briggs looks slightly chagrined: "This time," he says, "the launch date seems to be the real thing."

As Briggs begins to describe the VOIR project, a flutter runs through the room. "VOIR is the prime Office of Space Science candidate for FY '82," he says to the suddenly chill audience. "We're going to use the aerobraking technique to slow the spacecraft at Venus because the '86 opportunity is more difficult than the '84 chance."

Briggs is telling the scientists what they already know: that NASA has abandoned its Comet Halley mission, a mission that requires an FY '82 start. Then he begins to speak about Halley: "We have a mission, but it does not outprioritize the VOIR mission." The Halley/Tempel-2 mission is out, although several possibilities remain. The United States might hitch a ride with the Europeans, or cannibalize parts and build a cheap spacecraft, or modify an existing spacecraft. A Halley mission would cost about $250 million. "Halley is up in the air," says Briggs.

"Why is VOIR the priority mission?" a scientist asks Briggs.

"VOIR is the better mission," replies Briggs, "with better scientific return."

Not everyone agrees with Briggs. "If the man in the street were presented with unbiased data, he'd say space scientists were absolute fools," declares a supporter of a comet mission. "A mission to Halley is a unique opportunity to reach a bright comet."

"The first picture of Halley is so much more important than more geology," says another comet scientist. "We know so little about comets. Halley would be a first — something completely new."

Geologists, some say, dominate the NASA hierarchy and bias mission decisions toward geology. "VOIR could wait another two years; Halley is now — or 76 years from now. Halley is a chance we can't afford to throw away!"

Comet Halley is already well on its way back into the warm sunny regions of the solar system. "No amount of sophistry," states a strongly worded letter from one cometary scientist to other scientists at the meeting, "will alter these facts: either we explore Halley adequately in 1986, or we give up one of the two keystones of the comet exploration program for this century."

The other nations and space agencies which plan to fly missions to Halley — Japan, the Soviet Union, and the European Space Agency — do not possess the technical capability to send a "first class" probe of the kind NASA could send. On the other hand, the VOIR mission has the potential to revolutionize our understanding of planetary bodies. Earth and Venus are similar in mass and composition, but Earth, the slightly more massive, developed continents, oceans, and a planetary magnetic field while Venus did not. As a "twin" of Earth that didn't develop as a twin, the geology of Venus could shed significant light on Earth's geology — with possible economic and resource implications.

Even though VOIR does not have the pizzazz of the Halley mission, a successful VOIR mission offers more to the international scientific community than a successful "quick look" mission to Halley. VOIR data will also be of interest to a much broader group of scientists, including many geologists and earth scientists now not directly involved in space research.

NASA is backing the VOIR mission — and would try for funds to fly a Halley mission only if such a request would not harm potential funding for VOIR. Since it seems unlikely that both missions would be funded, NASA does not want to ask Congress for both and then get neither, or get Halley but not VOIR. VOIR will cost about half a billion dollars — or about twice the cost of a Halley mission.

Then there's the publicity angle: a comet mission could do a lot for the tarnished prestige of the United States. One danger is that such a comet mission could fail, sandblasted by bits of cometary debris despite the dust shield on the craft. Another danger is that the scientific return from a last-minute high-speed flyby might be minimal, but the effort invested by NASA would be large and costly, preventing the space agency from pursuing other programs. What will the public reaction be, in 1985, "when Halley is in the sky and there's no mission"? One answer, a rather cynical one, is that Comet Halley will not be visible in the northern hemisphere at this apparition, so its passing will be unnoticed by the public.

At present, NASA would like to participate in a cooperative venture, riding along on the European Space Agency's Giotto mission, and postponing its own comet explorations until the 1990s.

One of the highlights of the meeting was the keynote address given by novelist James Michener. The author of *Hawaii* and *The Covenant* has long been intrigued by space. He recounted his thrill at Fred Hoyle's remarkable theories ("and I read everything written in refutation of them"), the images transmitted back from Mars by Mariner 9 ("using digital bits of 'yes' and 'no,' 8-bit words, transmitted and reconstructed — it just blew my mind "), and the theories of Einstein ("a sweeping away of the old cobwebs").

"The Shuttle has created a launch vehicle capability problem."
Bruce Murray

"Since 1962, we've lived in an age of dazzling brilliance, an exact equivalent of the Copernican or Darwinian ages," he said, "but tonight, I stand here confused. If we are in the midst of an age of exploration, why doesn't the public realize it? Why is Congress hesitant? Why is the public apathetic? Why do we sit here while the Russians move ahead? — while they accumulate knowlege and experience that must inevitably put them ahead?"

He pondered a society bent on

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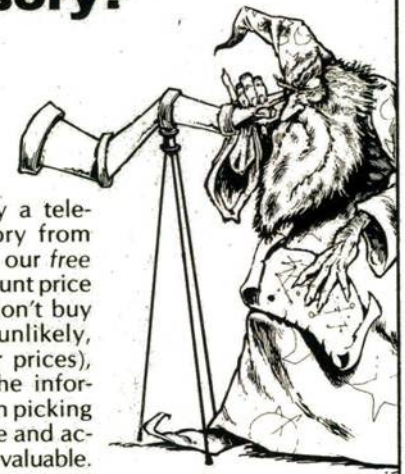

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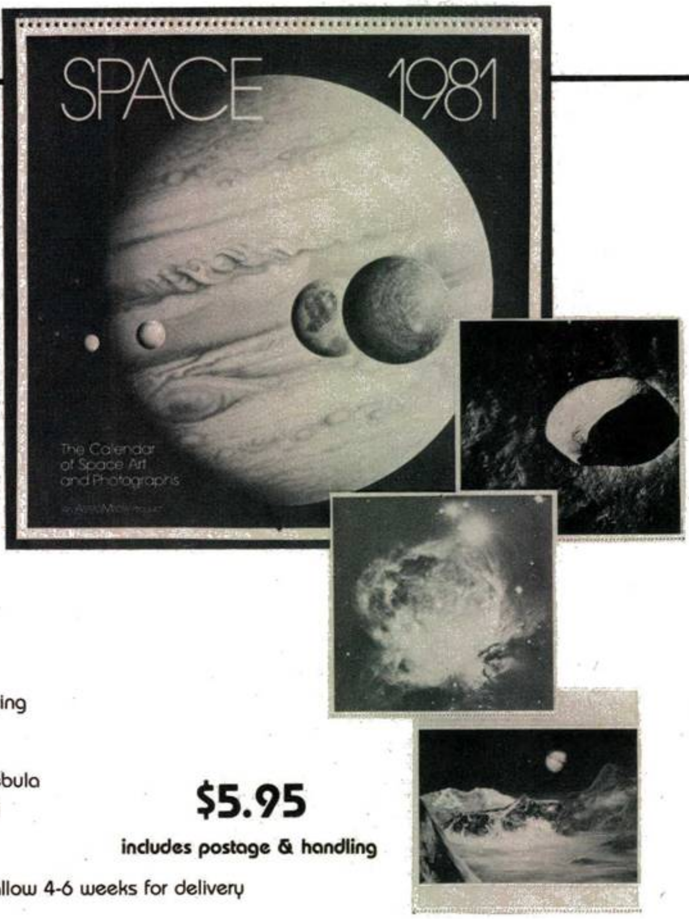

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destroying itself, and he voiced his concern for the nation. Tuning across the radio dial, listening to the charismatic preachers railing against evolution and humanism, he fears for our future: "Exiling the type of people doing the work upon which future exploration depends is perilously dangerous and self-defeating."

"I think it is absolutely vital that we preserve the cadre — that we keep our bright people on tap. The world is not going to become simpler — we are locked into it whether we like it or not — and if we don't [continue to explore], somebody else will. We can't predict the next half dozen blockbuster discoveries [that will change our society] — but I think it wise to caution the nation that these are coming."

In closing, Michener reminded the scientists of the fundamental relationship of man to nature: "I want our society to keep in touch with developments in the galaxies, in nature, because that's where we ought to be." Our safety and sanity, as individuals and as a society, reside in keeping in mind our place in the universe. "Wonder declines when one of us forgets he or she is a part of nature."

— *Richard Berry*

A Revolution in Amateur Astronomy

A revolution is taking place in amateur astronomy — for what other word could be used to describe the amazing advances in equipment and techniques we are now witnessing? The equipment currently produced for amateur astronomers is the kind we only dreamed of a decade ago. Then we could only dream — because some of it had not been invented or was found only at the world's major observatories. Furthermore, many techniques now used by amateur astrophotographers were only experimental ventures under development by the professionals.

One of the most noticeable aspects of the Equipment Revolution has been the Aperture Explosion. A decade ago, a typical amateur astronomer may have owned a telescope whose aperture was 2.4 to 4 inches. Although he might have aspired to a 6-incher, only in his wildest fantasies (or fantastic yearnings, for surely that is what they were) did he dream he would one day own an 8-inch. He knew, after all, only one person in his half of the country who owned a 10-inch (well, he really didn't know him, but once at a club meeting he had met a person who knew a friend of the 10-inch-owner, and that friend had even looked through it).

That was a decade ago. Let us now remind ourselves of the situation today. 10, 12, and even 14-inch telescopes seem to be everywhere — no star party seems complete without a big one. The Dobsonian Era has dawned, and with it the age of the "light-bucket" telescope. With this simple, inexpensive, and increasingly common type of mounting (more than that, really a new philosophy of building telescopes), the faint and far off vistas of our universe are open to our wondering gaze.

One member of our club has almost finished his 16-inch for hunting down faint comets. Another has told me of purchasing a 17½-inch mirror at a price that is reasonable for a high-quality 6-inch telescope. When his telescope is assembled, he will have an instrument with over eight times the light-gathering power of the 6-inch instrument he might been tempted to invest in a few years ago.

With his new telescope, he will literally be able to detect every NGC object. As most amateurs well know, of the thousands of objects in the NGC catalog, many are very faint and some are extremely faint. Think of seeing those faint objects in an amateur instrument!

This is a revolution that is leading to a greater enjoyment of the wonders of the night sky...

Still another member of our society recently told me of his latest project: building a 25-inch Dobsonian. This is not a wild dream; his previous projects have included some of the finest home-built telescopes any of us have seen. Who knows where the Aperture Explosion will end?

The Equipment Revolution is also operating at the eyepiece end of the telescope. New configurations of lenses, higher quality glass and other material used, larger oculars, rich field adapters, oculars with greater eye relief for a given focal length — all of these lead us toward a better view of the heavenly wonders. Add to that nebular filters (something that actually helps reduce the harmful effects of light pollution), and you have the makings of a mighty big breakthrough.

The equipment and techniques now used by astrophotographers enable them to produce stunning results as never before. Just look through recent issues of ASTRONOMY or attend the slide shows at current club meetings. Besides outstanding results, astrophotographers notice something else about the latest wave of equipment: it is more convenient to use. For a few years now, cold cameras have been bringing to amateurs the impressive results of chilled film emulsion. It used to be an inconvenient operation with the insertion of one frame of film at a time into the camera. Now a whole roll can be popped into the camera and rolled on as usual after each exposure. It no longer requires an hour's patient work to change from one frame to the next — that hour can now be spent in making three outstanding 20-minute exposures of deep-sky objects.

The latest addition to the list of techniques and processes assisting the astrophotographer is one I have found almost amazingly helpful — hypersensitized film. Gas-sensitized film gives outstanding results in the photography of nebulae and other astronomical objects. Not only is the color balance of the film improved, but there also is a tremendous gain in the sensitivity of the film to faint light from nebulae.

My first experimental use of sensitized film produced color slides of well-known nebulae, pictures of only five or six-minute exposure which were similar to ones that might have been exposed three or four times as long with ordinary film. Guiding for five minutes is easier than guiding for 15 or 20 — and there is only a fraction of the chance that Murphy's Law will take over. Some amateurs are, in fact, hypersensitizing film right in their own homes — something that until this year was rarely done except at the big observatories.

The list of new techniques and new kinds of equipment now used by the amateur could go on and on. Suffice it to say that the Equipment Revolution is a major part of the greater Astronomy Revolution now taking place. This is a revolution that is leading to a greater enjoyment of the wonders of the night sky by more and more people and a greater appreciation of the awesome vastness and profound complexity of the universe. Let the Revolution *continue!*

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eye
on the
sky

winter's waning constellations

by
Fred Schaaf

the wanderers

The end of March finds two pairs of planets almost exactly opposite each other in the sky. One pair is **Venus** and **Mars**, in conjunction early in April but also then near conjunction with the Sun. During all of March, in fact, Venus and Mars are already too far into the solar glare for observation. But while these two planets are converging on the Sun from either side (Venus from the predawn sky, Mars from the evening), the other pair of planets is superbly located for all-night viewing.

That other pair is **Jupiter** and **Saturn**, continuing their Great Conjunction. In March, both Jupiter and Saturn are moving backward, slowly to the west, and there is no true "conjunction" with both at the same right ascension as there was in January and February. But Jupiter and Saturn are extremely close to each other all month and reach the ideal observing position of *opposition* late in March.

When a planet is at opposition, it's exactly 180° away from the Sun and is visible in the sky all night long. Since it's also closest to Earth, the planet is both at its brightest and (in telescopes) biggest. In any given year, the opposition of a planet can occur on any day (or perhaps not at all, if Earth does not manage to catch up with the planet during the course of that year). It is therefore quite unusual for us to have Jupiter and Saturn coming to opposition this year not only in the same month, but even on the same day.

This day of "double opposition" is March 26, Saturn reaching the position at midnight (EST) 23 hours later than Jupiter. Only four hours, though, separate the times when they are precisely closest to Earth. On this night (and for roughly several weeks before and after), the awesome pair will first be visible low in the east as twilight deepens. Jupiter will be shining at -2.0, reigning all night as the brightest point of light in the Venus-less sky. This impressive magnitude is actually about the faintest Jupiter ever is at opposition, because it is now near aphelion (farthest from the Sun), but that slight lack is more than compensated for by the nearby presence of Saturn, itself glowing a deep gold +0.6. Both Jupiter and Saturn, by the way, will be getting brighter at oppositions until 1987, when they shine at -2.5 and +0.2, but will not then be near each other.

Their night-long visibility, brightness, and proximity to each other this month offer many fine opportunities for observation. Follow their movements in relation to each other and to the background stars in the heart of Virgo. You will notice that they finally move away from Gamma Virginis (Porrima) and head back towards Eta Virginis (Zaniah), which Jupiter almost reaches by month's end. At the same time, the small gap between the planets widens a bit after March 4, when they achieve a minimum separation of just 1° 03′, as they did on last December 31 and will almost do again in July.

Other naked-eye observing projects to try are a comparison of their color and a search for the jovian moons Ganymede and Callisto. For the unusual feat of spotting these jovian moons visually, they should be at or near their greatest elongation from Jupiter. Dark skies that are perhaps very slightly hazy would help to reduce the glare of the brilliant planet.

The positioning of Jupiter and Saturn this year is a very rare one, but it is only part of a wonderful multi-planetary arrangement which is much rarer still. The Great Conjunction of Jupiter and Saturn is a complex of three conjunctions in a seven month period which will not recur until 2238, but a Great Conjunction can happen even if the two planets are at opposition slightly more than one day apart — so the "double opposition" this year occurs even more infrequently. However, if you were observing the planets last year, you surely remember there was another three-event conjunction complex and double opposition, involving Mars and Jupiter. These two planets came to opposition together on the same day (only 12 hours apart) in February of 1980, and Jupiter and Saturn come to opposition together just 13 months later. Thus two major planetary events which occur only about once every century and a half happen for us in successive years.

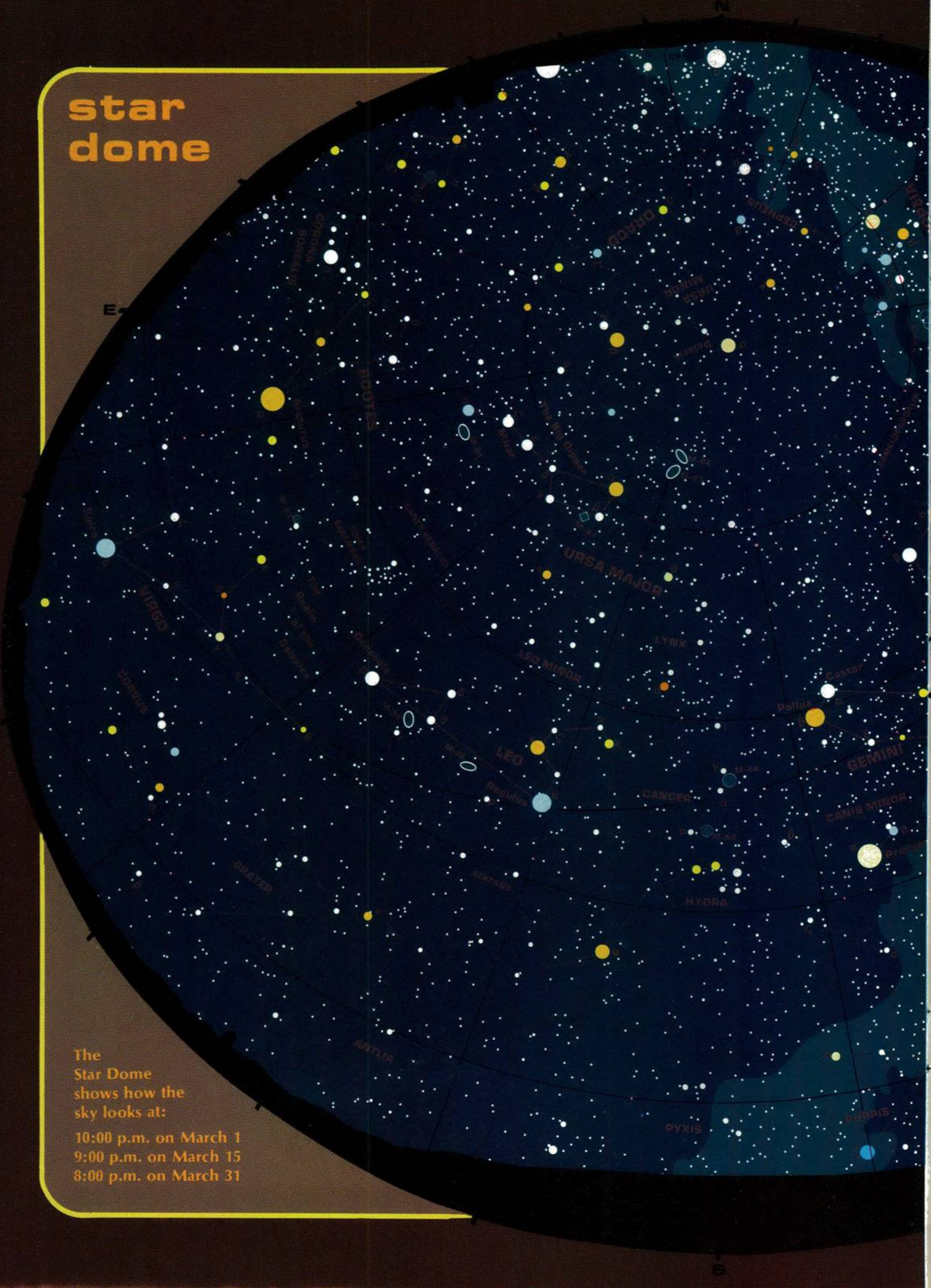
Those events are, you should remember, not insignificant ones of purely technical interest. A double opposition ensures planets together at their best and near each other for a period of many months. So the positioning of Sun, Earth, Mars, Jupiter, and Saturn in 1979-1981 is actually one of the finest and rarest planetary arrangements to have occurred in the last few thousand years!

The oppositions and conjunctions of these planets in the current period are, of course, only a few special highlight points in the much richer intricacy of the planetary dance. A vivid description and portrayal of the choreography of these worlds can be found in the 1980 and 1981 editions of Guy Ottewell's *Astronomical Calendar* (available from ASTRONOMY).

Any such account of the planets in these years must take in *all* of the worlds, for it is not only pairs of planets

Top: On December 14, 1980, Rick Schmidt photographed this Geminid meteor flashing past Orion. He used a 35 mm lens, 400 ASA film pushed to 800 ASA, and a 10-minute exposure. Bottom: An Air Force experiment that released barium in the upper atmosphere after sunset created this color fantasy. Photo by Igor Alexeff.

star dome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CORONA BOREALIS
DRACO
CEPHEUS
URSA MINOR
Polaris
BOOTES
Arcturus
Mizar
The Big Dipper
M-82
M-81
CAMELOPARDALIS
Spica
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CANES VENATICI
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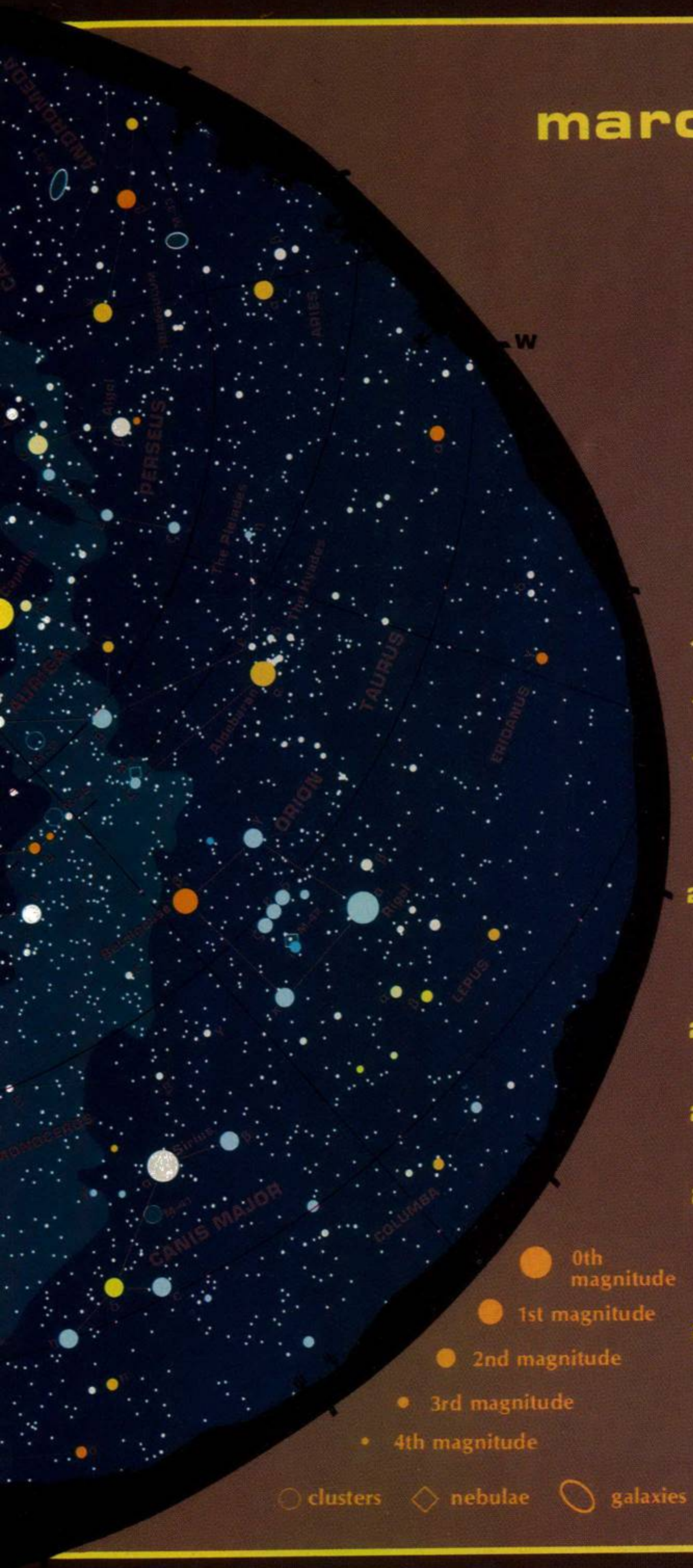
The Realm of the Galaxies
URSA MAJOR
LYNX
LEO MINOR
Denebola
CORVUS
Castor
Pollux
LEO
GEMINI
Regulus
M-44
CANCER
CANIS MINOR
M-67
Procyon
CRATER
SEXTANS
HYDRA
ANTLIA
PYXIS
PUPPIS

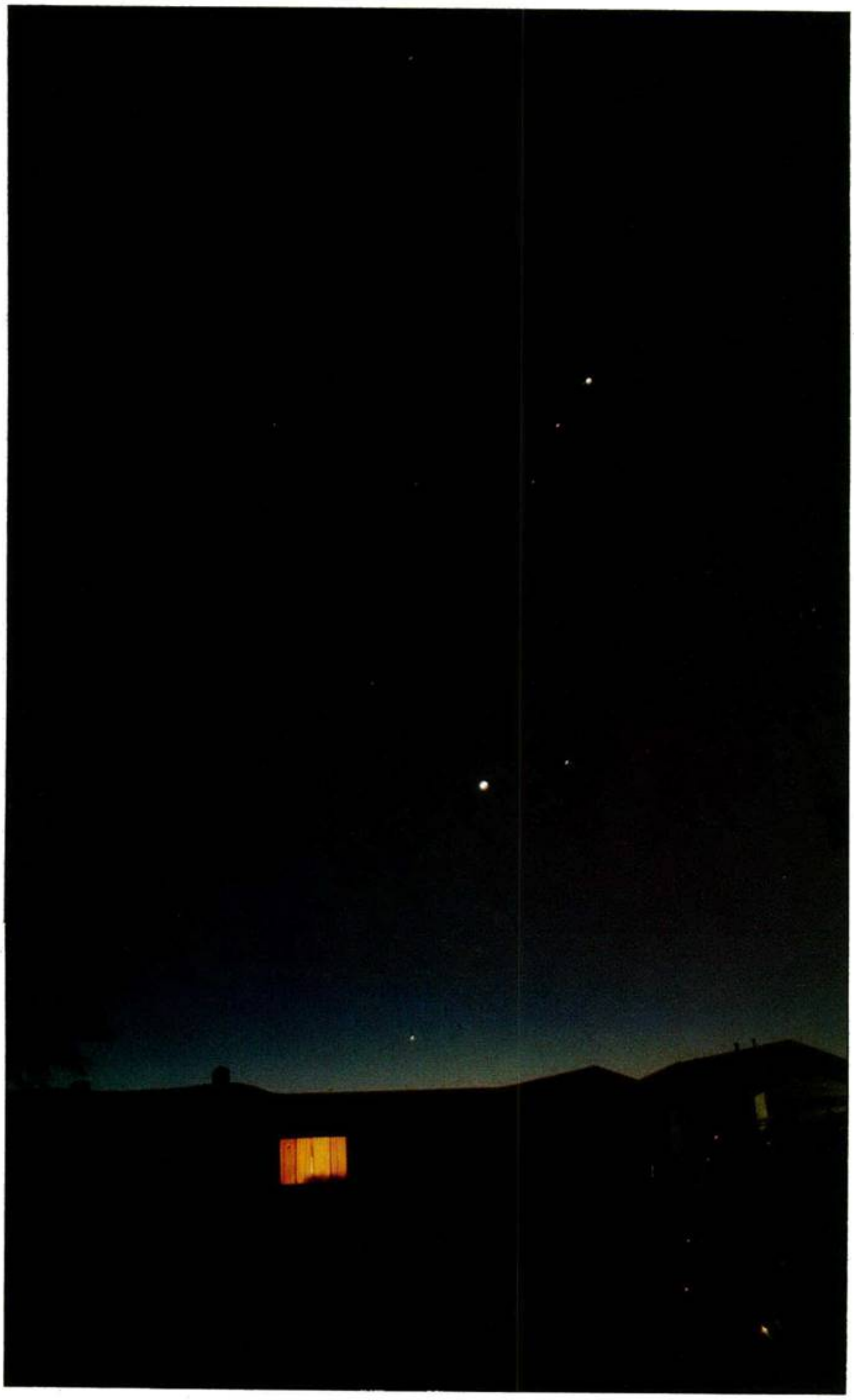
The Star Dome shows how the sky looks at:

10:00 p.m. on March 1
9:00 p.m. on March 15
8:00 p.m. on March 31


ANDROMEDA
ARIES
Algol
PERSEUS
The Pleiades
Capella
The Hyades
AURIGA
TAURUS
Aldebaran
ERIDANUS
ORION
Betelgeuse
M-42
Rigel
LEPUS
MONOCEROS
Sirius
CANIS MAJOR
M41
COLUMBA
W
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

march sky almanac

4th	The Moon, an extremely slender crescent, will lie very low in the east-southeastern sky this morning, below and to the right of Mercury. (Mornings between now and the 10th offer your best chances to spot Mercury.)
6th	New Moon at 5:31 a.m. EST.
8th	Moon at perigee (closest to Earth) this morning: 225,477 miles.
11th	Look for the Moon near the star Aldebaran tonight.
12th	First Quarter Moon at 8:50 p.m. EST.
15th	In the morning sky, Mercury is at greatest western elongation from the Sun today, but too low for easy observation.
20th	Full Moon at 10:22 a.m. EST. Spring begins at 12:03 p.m. Late tonight, the Moon will pass by Jupiter and Saturn.
24th	Moon at apogee (farthest from Earth) early this morning: 252,023 miles.
26th	Jupiter is at opposition to the Sun and visible throughout the night (1 a.m. EST).
27th	Twenty-three hours after Jupiter, Saturn also arrives at opposition and likewise will be visible all night (12 a.m. EST).
28th	Last Quarter Moon at 2:34 p.m. EST.



Four of the five naked-eye-visible planets lined up in the morning sky on November 20, 1980. At bottom center lies Mercury, higher and a little to the right are bright Venus and Spica, while higher still lie Gamma Virginis, Saturn, and Jupiter. Tom Sizemore used a 28 mm lens, 15-seconds' exposure, and 400 ASA film.

that are working into patterns with Earth. As if the extraordinary arrangements already mentioned were not enough, there is yet another one, which takes place as this month turns into April and which involves Earth, Sun, and four of the five naked-eye planets. Can you figure out what it is? If you can't, try re-reading the first paragraph of this section. (We'll look at the fascinating answer next month.)

One final hint is that the only planet not involved in this pattern is little Mercury. At mid-March, **Mercury** reaches its most extreme elongation from the Sun during all of 1981, almost 28°. But it's not very favorably placed for observers in the northern hemisphere, because the angle of the ecliptic is very shallow in the predawn sky here at this time of year. Most people will feel, however, that the northern hemisphere is favored by **Earth** reaching the vernal equinox (at 12:03 p.m. on March 20), for that will mark the beginning of spring in this half of our world.

the starry sky

March is one of those transitional months when a wide variety of stars and constellations can be studied. The bright winter constellations will be hastened out of the evening sky in April and May by the decrease in the length of nights (especially rapid for viewers in the U.S. around the time of the equinox). But March is a time when splendid winter constellations like Orion still hold the stage with the interesting newcomers of spring.

This month is the best for a convenient early evening comparison of the two most famous of all star patterns, **Orion** and the **Big Dipper**. Shining in the south, Orion the Hunter is much brighter, containing the first magnitude stars **Rigel** and **Betelgeuse** as well as its famous three-star belt of second magnitude stars. Sinking slightly ahead of Orion towards the west is **Taurus** the bull, with **Aldebaran** and the "V" of the **Hyades**, and, still farther west, the beautiful **Pleiades**. Both Orion and Taurus will begin to get captured by evening twilight next month, but not so the more northerly **Auriga** the charioteer with bright **Capella**, which is almost a north circumpolar (never-setting) star from the northern U.S.

On the other hand, **Sirius**, the brightest star, is well east of Orion, but far enough south so that it too will begin to fall into twilight late next month. Sirius shines in **Canis Major**, the big dog, while higher in the south is **Procyon**, the luminary of **Canis Minor**, Orion's lesser hound. Rounding out the circle or hexagon of brilliant winter stars are **Pollux** and somewhat fainter **Castor**, close together as the heads of **Gemini** the twins.

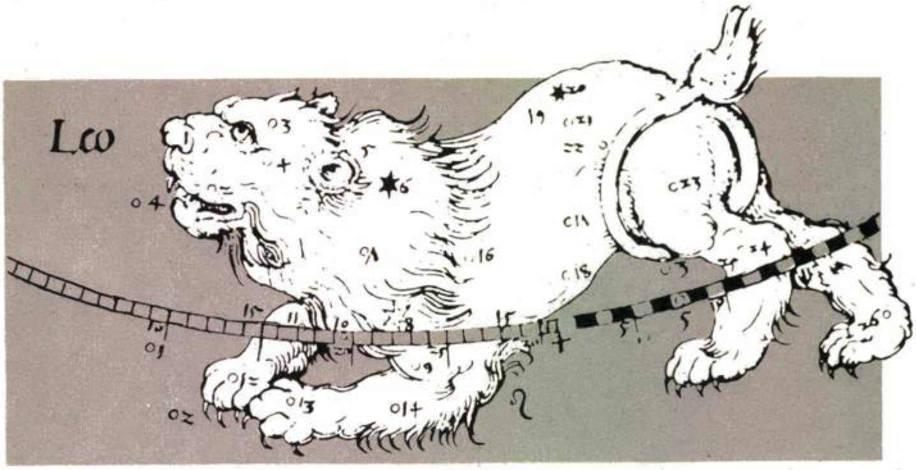
This month is a good time to rate the colors of bright stars and planets. Around 9-10 p.m. few of these objects are near the meridian, but most of the first magnitude stars of winter and spring (and this year, Jupiter and Saturn) are high enough up to judge their colors properly. (When they are low, the turbulence of the Earth's atmosphere can cause rapid color-changes.) Use the accompanying table for a numerical rating. Try to be accurate enough to use decimals — for instance, you might rate a particular star as "6.3". If you detect any peculiarities (such as any green) note this as well. If the colors seem too elusive to judge, use binoculars, but be sure to distinguish your rating with them from your naked-eye estimates. The human eye does not respond to colors in quite the same way that film or an instrument does, so these ratings are of considerable interest and value.

Among the objects with disputed colors is **Regulus**, in the constellation **Leo** the lion, huge in the southeast at mid-evening. Regulus marks the heart of Leo and is part of an asterism called the **Sickle**. The prominent Sickle, shaped like a backwards question mark of stars, forms the chest, neck, head, and dense mane of the mythical beast, while his hind-quarters are a right triangle somewhat farther east.

Leo is, of course, a constellation of the Zodiac, but there is another one between the lion and the twins: **Cancer** the crab. On a moonlit night (or any night in a large city) dim Cancer may look like only an emptiness midway between Pollux and Regulus. A closer inspection (or a view in a darker sky) reveals a few third magnitude stars, including a north-south oriented pair at the center of the constellation. And almost directly between the pair is an object so interesting it easily amends for Cancer's overall faintness: M-44, the **Beehive Cluster**.

M-44 is a large cluster, about 1½° across, containing dozens of stars when seen with even a small telescope. A few of these would be bright enough to glimpse with the naked eye in dark skies, if only the close proximity of the other members did not interfere. The Beehive as a whole, however, is a prominent third-magnitude ball of light, and in dark skies it's a marvelously strange sight, glowing unevenly across its extent. Even from the midst of a big city, it can be a fine object in a good pair of binoculars.

Below Cancer is the attractive little pattern which forms the head of **Hydra** the sea serpent. Not too far to the lower left of the head is orange (or slightly reddish) **Alphard**, the second-magnitude heart of the sea serpent. Hydra is the longest of all constellations east-to-west, and although its head is exactly on the meridian (halfway to the west horizon) at 9 p.m. in mid-March, the end of its tail is then still below the eastern horizon.



scale of colors for stars and planets

0 — Very blue
1 — Blue
2 — Bluish-white
3 — White
4 — Yellowish-white
5 — Light yellow
6 — Deep yellow or gold
7 — Orange
8 — Deep orange or light red
9 — Red
10 — Very red

In mid-evening during March, the Big Dipper (which we will look at more closely next month) is in the northeast, and still low in the east are the two brightest stars of the spring patterns. **Arcturus** can always be found by following the curve of the Big Dipper's handle outward, but it is seldom necessary to use this method because the star's brightness and distinctive orange hue make it prominent indeed.

This spring, of course, even Arcturus is easily outshined by a planet in its general area of the sky: Jupiter. The splendid Jupiter-Saturn pair is an excellent guide this year to the second brightest spring star, first magnitude **Spica**, which rises almost due east and is the lucida (brightest star) in **Virgo** the virgin.

skylore

The lion, with his kingly crown of mane, is appropriately represented in the heavens. Certainly few star patterns are as majestic, or as similar to their imagined forms, as our constellation Leo.

Leo could be any of the lions which loom even larger than life and are so powerful in legend and emblem. Not surprisingly, however, he is usually identified with the most famous such beast in Greek mythology, the Nemean Lion who was the opponent of Hercules.

The conquest of the Nemean Lion was the first of the great Twelve Labors assigned to Hercules. While the tale of their battle is famous, some of the lesser-known details of this myth are of special interest to those interested in astronomy. For the Nemean Lion was no mere earthly beast who was just very strong. Instead, he was a magic creature who is said to have fallen from the Moon. His parents were sometimes said to be Zeus and Selene, goddess of the Moon, and his sisters (the other children of this particular divine couple) were Nemea, Pandia (famed for her beauty), and Erse (the dew). But it is tempting for us to speculate that the coming of the Nemean Lion was a meteor fall, which later was remembered and woven into the rich Hercules story.

Less than two centuries ago, the idea that "rocks" could actually fall from outer space was scoffed at by scientists, but today it is even thought quite possible that certain meteorites on Earth's surface may have originally come from the Moon. These strange, glassy objects are called "tektites." They are presumed to be meteorites, but unlike all other kinds, they are found only in certain areas of the world. One theory is that they fell only on the hemisphere of Earth turned towards the Moon when a giant meteoroid struck the lunar surface and ejected them several hundred thousands of miles to cause a "Moon-shower" across large areas of the Earth.

Could this event really have occurred? There is even a strong chance that the lunar crater Giordano Bruno (on the Moon's far side) was formed by just such an event less than a thousand years ago, and that the impact explosion was observed by some monks at Canterbury. (See "Is There a 'New' Lunar Crater?" by Joel Davis, ASTRONOMY, January 1979.) Some of us may think this probably factual story even more marvelous than the myth of the Lion, but perhaps the most amazing thing of all is that the two might be connected.

We do not know if meteors actually went into the making of the leonine myth, but we are told that the Nemean Lion ravaged the isthmus of Corinth, slaying people and destroying the land. No one could end this dreadful rampage because no weapon was capable of wounding his magically impenetrable hide. Could even Hercules vanquish such a beast? The first Labor was by no means his easiest, but in the end the hero triumphed by using his supreme strength to strangle the great lion. The skin of the Nemean Lion became not only the trophy but the cloak of Hercules, which he wore on all of his later adventures, and later among the stars in his shape as a constellation.

ASTRONOMY IN FOCUS

How Easy to Err

Sir / In response to my review (ASTRONOMY, Dec. 1980) of Tauber's *Man's View of the Universe*:

In the section of my review wherein I noted some errors in Tauber's generally excellent book, I wrote: "Huggins' telescope (p. 202) was a refractor, not a reflector." Somehow, "refractor, not a" got lost. What an appropriate reminder of how easily errors slip in!

Michael J. Crowe
Notre Dame, IN

Hubble Diagram

Sir / We would like to comment on two of the illustrations that appeared with our recent article "Why All the Fuss about Quasars?" (October 1980).

The first comment concerns the radio maps on page 11. The figure really should be titled "The Structure of Galaxies." All the objects shown are associated with galaxies, and, in fact, all but M-87 are members of a class of objects called "head-tail" radio sources. These sources seem to show the effects of motion of the parent galaxy through the tenuous gas that exists in the intergalactic regions of clusters of galaxies. Some quasar sources do show structure similar to that of M-87: two lobes of emission well-separated from the central object which may show emission as well; but none are known to show the head-tail kind of structure.

The second comment concerns the "Hubble Diagram" on page 8. This is not really in the form that astronomers usually call a Hubble diagram. A Hubble diagram is a plot of the redshift of galaxies and quasars against their apparent magnitudes. When certain classes of galaxies (typically, elliptical galaxies which are the brightest galaxies in clusters and galaxies associated with strong radio sources) are used to make the diagram, a very good relationship is found between apparent magnitude and redshift. By assuming that the galaxies are all intrinsically equally bright and that redshifts really represent Doppler shifts due to velocity (an assumption disputed by some astronomers, especially for quasars), astronomers arrive at the concept that larger redshifts mean greater distances from us.

The value of the constant of proportionality between redshift (or recessional velocity) and distance is called the Hubble constant. Deriving its value is a very complex procedure and its exact value is still somewhat uncertain, but seems to be in the range of 50-100 km/sec of recessional velocity per megaparsec of distance. (One megaparsec is 3.26 million light-years.) The diagram on page 8 assumes that the Hubble law is valid, with a constant of about one hundred km/sec/megaparsec, and shows the derived relationship between redshift and distance.

Since astronomers have few accurate measures of distance beyond about 10 or 20 megaparsecs, the straight-line relationship in the upper right corner of the figure, especially for quasars, must be regarded as a result derived from the Hubble law for nearby galaxies, rather than the establishment of the Hubble law itself. We believe the given diagram is correct, but some of our colleagues would argue that in a true Hubble diagram, the quasars do form a scatter diagram of redshift versus apparent magnitude. The scatter exists because there is either a wide range of intrinsic luminosities (the conventional view) or quasar redshifts have nothing to do with distance (an unconventional view), or both. Galaxy Hubble diagrams also show much scatter unless specific kinds of galaxies are chosen that have the same intrinsic luminosity (a "standard candle"). Probably, we just don't know how to identify the right kind of quasars to pick!

David B. Shaffer
NASA Goddard Space Flight Center
Greenbelt, MD

Gregory A. Shields
University of Texas
Austin, TX

3-inch Spectacular

Sir / I am 15 years old and I'm writing this at 11:45 at night, having just come in from stargazing. I've had a 3-inch reflector for about 8 years, and it's been fine for the Moon and an occasional planet, but I never thought it could do much else. After all, everyone else interested in astronomy seems to have at least a 6-inch. A 3-inch? Hah!

So I've been trudging along with my dad's baseball binoculars, and I had seen the Orion Nebula (M-42) and the Andromeda Galaxy (M-31) but that was it. I had been able to detect them, but that was all.

The finder on my telescope is not that terrific, so my main way of finding things is to set it up and point the tube. Then I jiggle it until the object pops into view.

Tonight it dawned on me that in size there really isn't much difference between M-42 and the Moon. The Moon is just a little brighter.

So I bundled up (it was a bit cold), took the thing out, aimed it, looked in the eyepiece, and about fainted. It was actually there!

None of the spectacular reds or blues seen in photos were to be found, only a subtle greyish-green cloud with four stars nestled inside. But is was much better than any picture or photograph. This was the real thing!

I stood there staring in awe for over a half-hour, and if I hadn't discovered that my hands were numb from the cold, I would probably still be out there.

Rick Ramsey
Englewood, OH

Sic Transit Gloria Mundi

Dear ASTRONOMY / It's a bit (well, actually a lot) late, but I wanted to thank you-all for your participation in KCET's auction fundraiser. All the subscriptions you donated were sold for more than their actual value — most gratifying! I wish all our donations sold that well.

The other day, well, longer ago than that really, I went wandering in the warehouse. All sorts of props and things from the *Cosmos* series are there, or at least they were then — planets and Saturn rings crammed in amongst art boards and rolling tables. S'funny...Jupiter has a trapdoor kind of thing in the Red Spot. I have no idea what it's for, but when you open it and shout inside, it makes a dandy echo....

The miniature martian canyon in the boneyard is long gone — it's probably part of some sanitary landfill project somewhere by now — sigh!

Oh yes — thank you for another year of beautiful magazines. Murray Chris Moose and Hippo Gnu Ears!

Elaine Hampton
Burbank, CA

Cold Weather Hassles

Sir / In reference to the Equipment Atlas, "Keeping Warm While Stargazing" (December 1980): Although Mr. Huffman covers his subject well, he neglected to comment on winterizing your telescope. Rack-and-pinions or refractor drawtubes can freeze solid in very cold weather, especially if the telescope is damp. Forcing the soft pinion gear can strip a rack very quickly. Worm or spur gears in telescope drives can become stiff and are liable to introduce more backlash. And you have to be careful if you grease them, since too much will make the whole drive mechanism sloppy.

Cold cameras are great but the regular 35 mm SLR isn't really built to take the cold and the film can be hard to advance — and even tear if forced. The new automatic cameras with electronic parts can be damaged in sub-zero weather.

There is a host of other equipment problems that you can run into. So, as well as covering up for cold weather observing, be sure your equipment is ready for the cold. I know — I have run into all of the above problems at one time or another!

C. E. Spratt
Victoria, BC
Canada

Mother/Daughter Complaint

Dear Sir or Madam / My (clever) child showed me the article "How to Buy a Telescope for a Child" in your October 1980 issue. It was highly informative and will probably result in our buying a telescope.

My enthusiasm for the article was diminished, however, by your frequent references to the "father/son" project of building a telescope. I resent your sexism. Please be advised that the project in our house will be a father/mother/daughter project.

DeEtte Wald Beghtol
Seaside, OR

Dear Ms. Beghtol / We are fully aware that women like astronomy, read our magazine, and buy telescopes. With some care, we used, throughout the article, the terms "child" or "kid" rather than the masculine pronoun.

"Father/son," used twice, was placed in quotes to indicate that the term was not intended to indicate sex.

We trust that you, your spouse, and your child will enjoy the telescope and the celestial sights it will show you.

Science and Art

Sir / My son gave me ASTRONOMY as a birthday present. It's one of the nicest gifts I've ever received. Being an artist, a maker of paintings, I need creative and aesthetic stimuli for my imagination which the current avant-garde periodicals, with their cold almost materialistic feeling toward the creative works of mankind, fail to provide. No matter how scientific and analytical articles about remote objects in space may seem, I always sense an element of being-in-awe and romance-of-the-unknown in your writing.

I've taken my 4-inch reflector out again at night to renew my acquaintance with the objects in the night sky. In this period of art, those who are involved in the arts should not only leave their studies during the day to observe nature, but must also renew their interest in the heavens at night.

Bernard Zalusky
Newport Beach, CA

behind the scenes

revising the reviews

When our venerable Astronomy Reviews department was established, "book" was carefully omitted from its name. Although we have, from time to time, taken advantage of the implied freedom to review new products other than books, books have been, for the most part, the substance of this department. Now, in a rather low-key way, I'd like to let you know that we plan to expand the function of Astronomy Reviews to cover a wider variety of astronomy-related products.

For several years, we toyed with the idea of creating a department listing new products. Many "hobby" magazines have such a section — usually containing rewritten copy supplied by the manufacturer. I even write a column called "What's New" in TELESCOPE MAKING magazine that is precisely that.

But, from the telephone calls and letters I receive (far more, in fact, than I can hope to answer), I see that you — our readers — are fully aware of the new products that exist. What you really need is an independent opinion, the report of someone who has tried the product and can judge whether it's all it's claimed to be. That clearly could be a new function, above and beyond books, for Astronomy Reviews.

This month you will find a review of Fujichrome 400, a new high-speed color transparency film. Reviewer David Healy, comparing new and existing films, has performed a useful service for all deep-sky astrophotographers. Although books will continue to be the mainstay, we invite informed and balanced reviews from thorough and careful reviewers.

Sincerely,

Richard Berry

Richard Berry

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observing the gas giants

gazer's gazette

On antique maps of Earth, the distant and unexplored regions labeled "Terra Incognita" were sometimes shown populated by strange, exotic creatures. "Here be monsters," the cartographer might note, as though warning the ignorant and unwary to keep a safe distance. Fortunately, intrepid explorers ignored such admonitions, or simply forged bravely onward, eager for a chance to find something entirely different.

Earth is now fairly well explored, and what monsters there are (except maybe for that putative denizen of Loch Ness, the Abominable Snowman, Big Foot, and an occasional sea serpent) have been thoroughly identified, cataloged, photographed, and studied. Our own time finds us exploring a much larger realm — the solar system. And far out in the distant reaches of the solar system there are in fact *true* monsters — huge and solemn, cold and compelling, and very, very different from anything we have found in our immediate neighborhood. They are sometimes called the *gas giants* and their names are Jupiter, Saturn, Uranus, and Neptune.

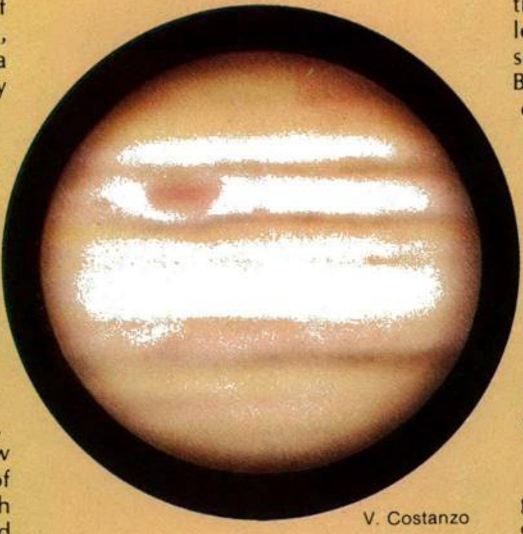
The first explorers are even now scouting this "Caelum Incognitum" of the solar system: explorer-robots with names like Pioneer and Voyager. And the gas giants are indeed turning out to be monstrous: Jupiter with its fierce radiation belts, Saturn with its incredible storm-winds.

One of the fascinations of astronomy is the opportunity to explore the strange and entirely different. Now, when we are learning so much about the outer regions of our planetary system, is perhaps a good time to step back and consider the possibilities of an Earth-bound "exploration" of the gas giants from your own backyard. What can you expect to see, and how do you go about looking for it?

Equipping for Exploration

Jupiter and Saturn — the largest planets and, of the gas giants, the nearest — are easily visible to the naked eye. In fact, they will normally rank high with the brightest objects in the sky after the Sun and the Moon. But the other two, Uranus and Neptune, will require some optical aid to be seen at all (though some have been able to spot Uranus visually in a clear, dark sky).

Binoculars will allow you to see the four bright "Galilean" satellites of Jupiter and will show Uranus as a starlike point of light, but for anything more you will need a telescope. Any telescope, no matter how small, will open up a wide range of observations to the careful observer, but some telescopes are better than others for planetary viewing. Of course, the larger your telescope's aperture, the more you will be able to see, but fascinating observations can be done with even a small scope. Whether you use a refractor or a reflector, you need as long a focal length as possible. Short focal length, "richest field" telescopes aren't very suitable for planetary observations.


V. Costanzo

You will want a long focal length for planetary observation because high magnifications are necessary to discern detail, and magnification depends on the focal length of the primary as much as on that of the eyepiece. A long focal length combined with a particular eyepiece will result in a higher magnification than that same eyepiece used with a short focal length objective. This is one time you can dust off those short focal length, high-power eyepieces you seldom use with nebulae and clusters! But be careful: your magnification is effectively limited by the stability of our atmosphere, so on a bad night don't try to push powers that only magnify atmospheric distortions.

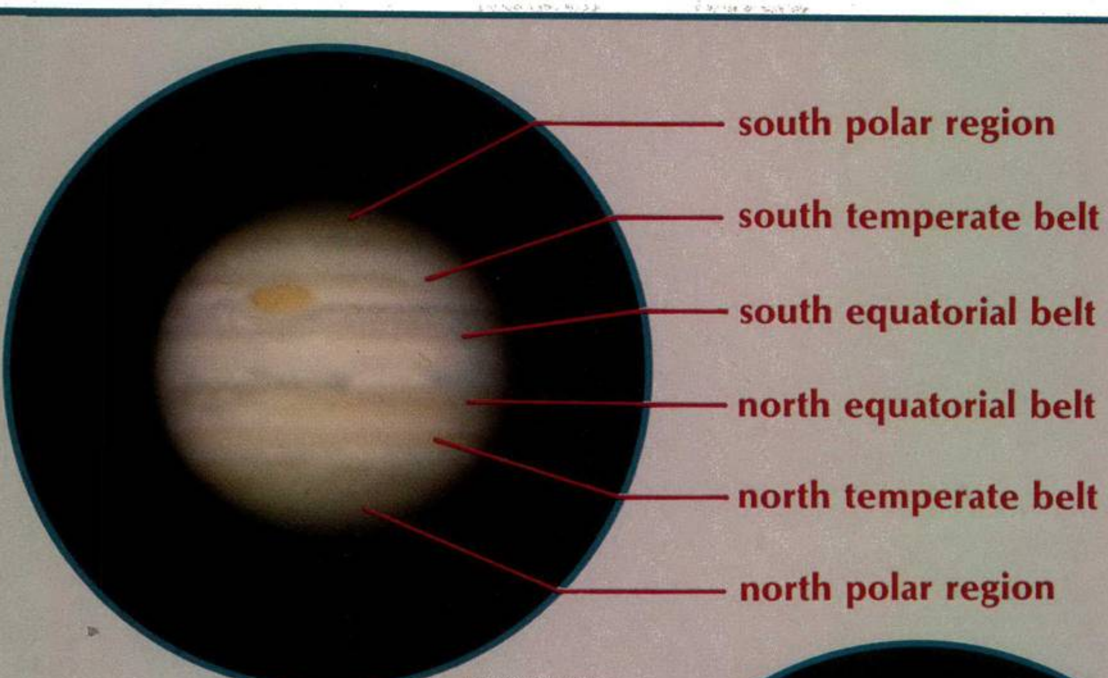
You'll also want to carry with you a good almanac (for plotting positions and spotting and identifying satellites), a star atlas (to assist in locating Uranus and Neptune), notebook and pencil (to record your observations), and a red-lensed flashlight (to help you use your equipment in the dark).

Jupiter

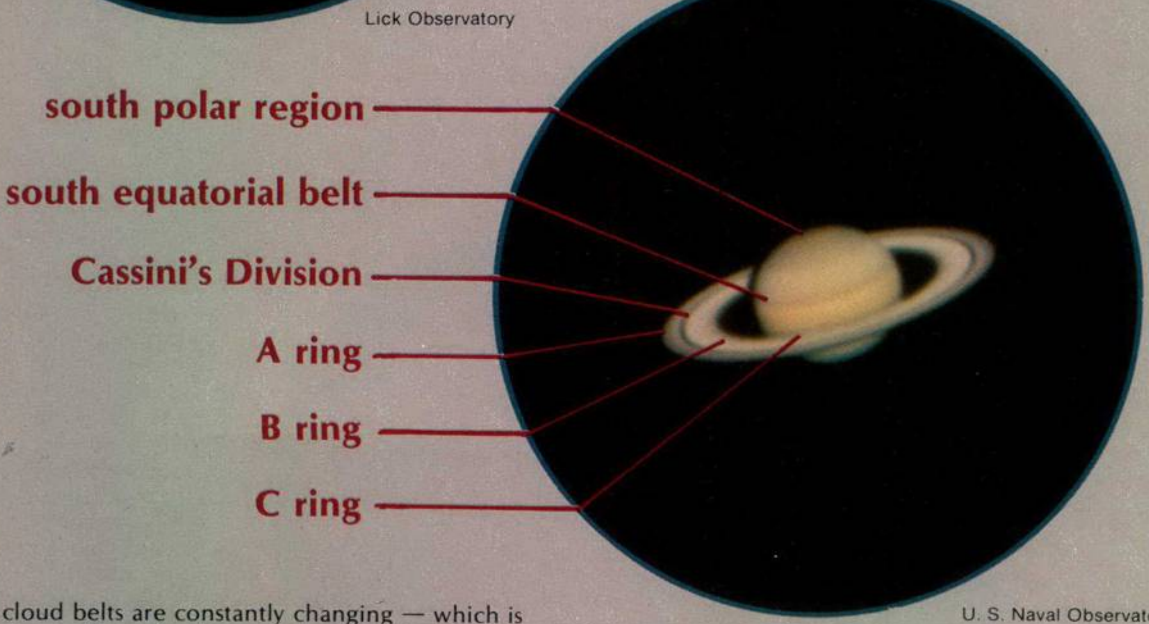
Jupiter is truly the giant of the giants: Its mass is 2½ times that of the other three gas giants combined. It is also the easiest of all the planets to observe. At maximum, its apparent diameter is greater than attained by any other planet except Venus — which at maximum shows only a thin, featureless crescent. As an outer planet, Jupiter is always full or nearly full to our view. Furthermore, Jupiter doesn't vary much in comparison to our closest neighbors Venus and Mars in apparent diameter over the course of a year, so it is almost always worth observing — except when it's too close to the Sun to be seen at all.

As with all the gas giants, we do not

belts, zones, and spots


south polar region
south temperate belt
south equatorial belt
north equatorial belt
north temperate belt
north polar region

Lick Observatory


south polar region
south equatorial belt
Cassini's Division
A ring
B ring
C ring

U. S. Naval Observatory

Jupiter's cloud belts are constantly changing — which is why the planet always fascinates — belts can become zones while spots come and go.

Lunar & Planetary Laboratory

Lunar & Planetary Laboratory

Hale Observatories

see a "surface" on Jupiter, but only its cloud tops. These clouds, though, are fascinating to watch; swirling around the planet in streaks and bands, they present an ever-changing spectacle. Since Jupiter rotates once every 9 hours 50 minutes, you'll find the appearance of the planet changing relatively rapidly.

Most observers record their observations of cloud detail by making drawings of the planet, and this is something you'll find both rewarding and easy to do. It helps to prepare in advance blank ellipses to represent the jovian disk — the easiest way to do this accurately is to buy a 70° ellipse template at a drafting or art supply store. But don't be overly ambitious — use ellipses only about an inch or so in diameter, or you'll be tempted to fill in details you don't actually see.

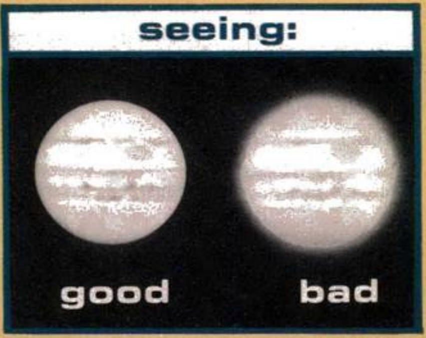
Use a soft (HB or #2) pencil to sketch in the belts and other details you observe, and make notes of any colors you can detect. This won't be easy, but the colors are there — as the Voyager images show clearly. And don't forget to note the date, time, instrument, eyepiece, magnification, and seeing right on the drawing.

Many people have heard of Jupiter's Great Red Spot and want to see it, but this is not always easy. The Spot may be on the other side of the planet at just the time you look for it, or it may have "faded" considerably and be difficult to detect. The appearance and color of the Red Spot do change over the years, and currently it's not very prominent.

Of course, the larger your aperture the more detail you'll be able to observe during our atmosphere's "quiet moments" of superb seeing. You'll also find your ability to detect subtle shadings and elusive markings will increase with experience. To help reduce glare and increase contrast, try observing with an orange (Wratten 21) or yellow (Wratten 8-12) filter. (But use a blue filter to make the Red Spot stand out better.)

You can make interesting observations of some jovian moons with a telescope of any aperture — or even a good pair of binoculars. The four satellites — known as the "Galilean" satellites after their discoverer — are all around magnitude 5-6 and very easy to spot. The chart in each issue of ASTRONOMY will guide you to the correct identification of each satellite, and even experienced observers find the changing aspect of this "miniature solar system" fascinating to follow from night to night.

With a little more experience, you'll want to observe transits and occultations of the moons. Since the plane of the satellites' orbits lies almost exactly in the same plane as the orbit of Earth, each satellite (except sometimes Callisto) will pass in front of Jupiter and then behind it on each orbit. It's also fun to track the shadow of a satellite across the jovian disk, and to look for the rapid disappearance or reappearance of a moon entering or leaving Jupiter's shadow.



V. Costanzo

Saturn

The famous rings of Saturn are the most asked-for "sight" at any public starnight — and indeed, the ringed planet itself is one of the most beautiful objects in the sky. There are three rings observable from Earth, but the innermost, the C or Crepe ring, is so diffuse that the planetary disk can be seen through it and it's difficult to detect in small instruments.

The other two — the A and B rings — are easily seen in any aperture telescope (except when Earth passes through the plane of the ring system, as it did last year). Somewhat more difficult is the dark gap between the A and B rings, known as Cassini's Division, although Cassini himself discovered it with a 2½-inch telescope at 90 power. Also try to see, if you can, the shadows cast on Saturn by the rings, and on the rings by Saturn (the latter is easiest to see when Saturn is at quadrature — in late June to early July this year).

As Saturn moves around the Sun in its 29½-year orbit, the angle from which we view the rings changes. The rings, lying in the plane of Saturn's equator, are tilted 27° to the plane of the ecliptic, so the greatest "openness" the rings can achieve is 27°. Twice during each orbit, or about once every 15 years, the rings are aimed edge-on at us and disappear entirely from our sight. Since this "ring passage" just occurred last year, the rings will be opening up more and more over the next several years. Currently we are viewing the north side of the rings.

But there's much more to observe here than just rings. Though lacking permanent features such as Jupiter's Red Spot, and — because of the overlying layer of haze — having much more vague and indistinct markings than Jupiter, Saturn's clouds do present their own version of belts and bands. Try using the same filters recommended for Jupiter to make the markings more apparent, and be sure to record your observations by making sketches.

We now know that Saturn has at least 15 satellites, and probably more, but of these only six or perhaps seven at most can be observed with amateur instruments (apertures up to 14 inches). Most of the other members of this complicated system are beyond the reach of even our largest telescopes.

One satellite in particular will be visible in even the smallest telescopes:

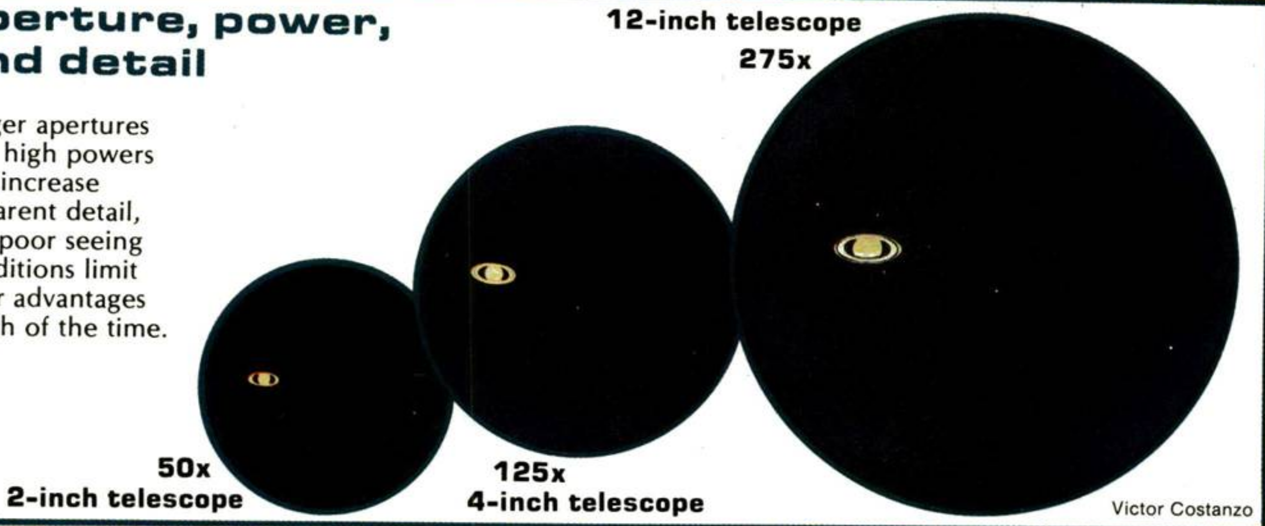
observing the gas giants

Planet	**Jupiter**	**Saturn**	**Uranus**	**Neptune**
Apparent Diameter (Equatorial)				
Maximum	47"	19.5"	3.9"	2.5"
Minimum	28"	14"	3.5"	2.3"
Magnitude				
Maximum	-2.5	-0.2	+5.7	+7.6
Minimum	-1.2	+1.5	+6.1	+7.9
Observable Satellites	4	1 to 6	2	1
Sidereal Period	11.86y	29.46y	84y	164.8y
Synodic Period	399d	378d	369.7d	367.5d
Distance from Sun (Astronomical Units)	5.2	9.5	19.2	30.1
Equatorial Diameter (Earth = 1)	11.2	9.5	3.9	3.5
Mass (Earth = 1)	318	95.2	14.6	17.3
Inclination of Axis	3°	27°	98°	29°

Sidereal Period = orbital period relative to the stars
Synodic Period = time between successive oppositions

aperture, power, and detail

Bigger apertures and high powers will increase apparent detail, but poor seeing conditions limit their advantages much of the time.



Victor Costanzo

Titan, Saturn's largest moon by far and so far the only satellite in the solar system known to possess a substantial atmosphere. Shining at a mean opposition magnitude of 8.3 and well-separated from the brilliant disk (3' of arc at elongation) and rings, Titan is easy to spot — provided you know where to look. Use the chart and tables provided in the *Astronomical Almanac* (see box) to locate this mysterious moon, larger than Mercury and in many ways a planet in its own right.

The other observable satellites of Saturn in order of their ease of observation, along with their mean opposition magnitudes, are Rhea (10.0), Dione (10.7), Tethys (10.6), Iapetus (10.8), Enceladus (11.7), and possibly Mimas (12.1). The last two will be especially difficult not only because of their faintness but also because of their proximity to the brilliant planet itself. Again, refer to the *Astronomical Almanac* for positions relative to the planet.

Uranus

Moving farther out in the solar system, we find observational possibilities dwindling rapidly. At about twice the distance of Saturn we encounter the much dimmer planet Uranus. Less than half the diameter of Saturn, Uranus presents a tiny disk just under four arc-seconds in diameter. Most observers find the disk pale greenish in color, but no details are visible. We now know that Uranus has several thin, very dim rings, but don't expect to spot them in *any* telescope, no matter how large!

Uranus has five satellites, all of which orbit the planet in circular paths in the plane of Uranus' equator. Because of the high inclination of Uranus' axis to the plane of its orbit, we are now looking down almost directly on the north pole of the planet, so the orbits of the satellites appear nearly circular to us. Their names are beautiful: Ariel, Umbriel, Titania, Oberon, and Miranda, but of these only two — Titania and Oberon — are within the reach of large (eight inches and up) amateur instruments.

To look for Titania and Oberon (which never become brighter than about 13th magnitude), plot their predicted positions on the chart provided in the *Astronomical Almanac*. (Be sure you know which way is north when you look through your eyepiece.) If you think you have spotted them, confirm your observation over the next few nights by looking for their orbital motion. Titania takes 8.7 days to complete one orbit, while the slower and more distant Oberon circles the cold giant every 13.5 days.

Neptune

Reaching out to distant Neptune, we find little to discover. There are only two observations which an amateur can reasonably hope to make here — aside from locating the planet in the first place, which is no mean feat in itself and, with a small telescope, *all* you can do.

Those with at least six inches of aperture have a chance to see Neptune as a disk rather than just a point of light — provided the seeing is good and a high magnification is used. But don't expect to see any surface details. The tiny grayish disk never varies much from about 2½ seconds of arc in diameter, and the illumination out here in the suburbs of the solar system is barely more than a thousandth what we receive on Earth.

The only other observation you can make is to spot Neptune's huge moon, Triton. Circling Neptune in a close, nearly circular orbit in just under six days, 13th magnitude Triton can be glimpsed in 8-inch or larger scopes (some have seen it under excellent conditions with only six inches of aperture). Consult the *Astronomical Almanac* to determine the satellite's exact position with regard to the planet, or you might easily mistake a dim star for Triton.

Exploring the gas giants with your telescope can be an exciting adventure for any astronomy enthusiast, from the beginner with a small telescope or even just a pair of good binoculars, to the advanced observer in his own observatory. These distant, different, and endlessly fascinating giants of the solar system offer both challenges and rewards to all, and you'll find that your observing abilities will increase and sharpen with time and experience. All four of the gas giants come to opposition over the next few months — Jupiter and Saturn this month, Uranus in May, and Neptune in June — so this is a good time for you to join the Pioneers and the Voyagers on their missions of discovery.

— *Dewey Schwartzenburg*

the astronomical almanac

Known until this year as the *American Ephemeris & Nautical Almanac*, the annual volume published by the U.S. Naval Observatory is now entitled *The Astronomical Almanac*. You can look at it (for free) at your public library or buy it for $13 (hardcover only) from the U.S. Government Printing Office, Washington, DC 20402. The 1981 volume is an indispensable mine of information for the observer.

Gas-giant planet watchers will find the tables of physical information (size, magnitude, times of satellite elongations, etc.) immensely helpful in planning observations — and understanding what they see.

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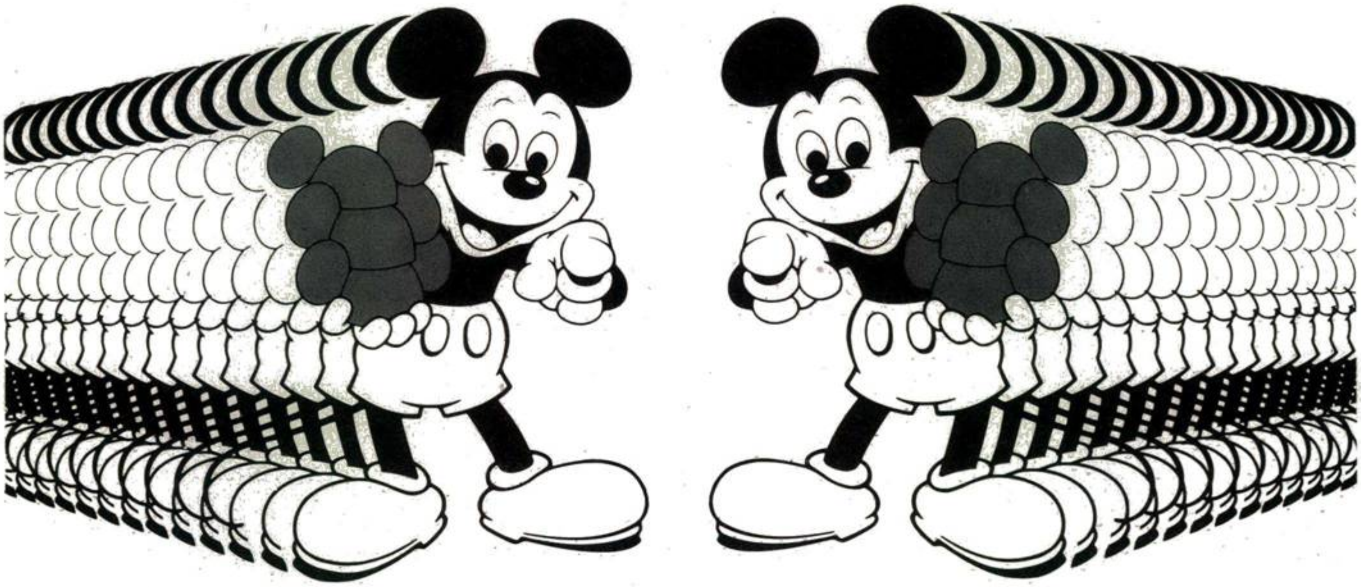

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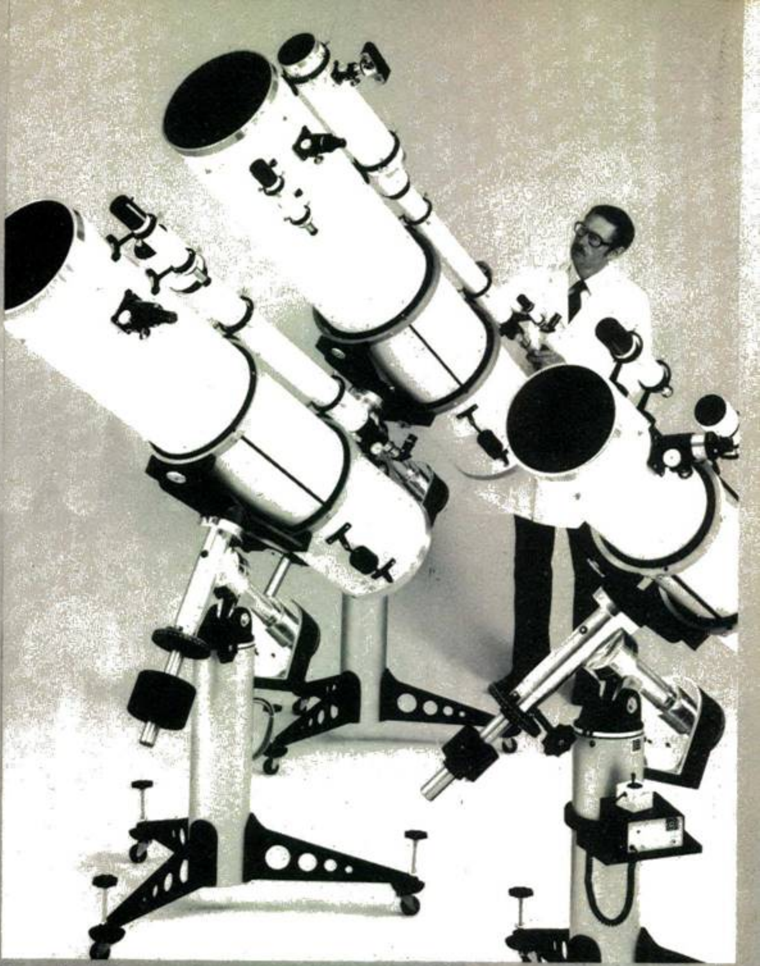

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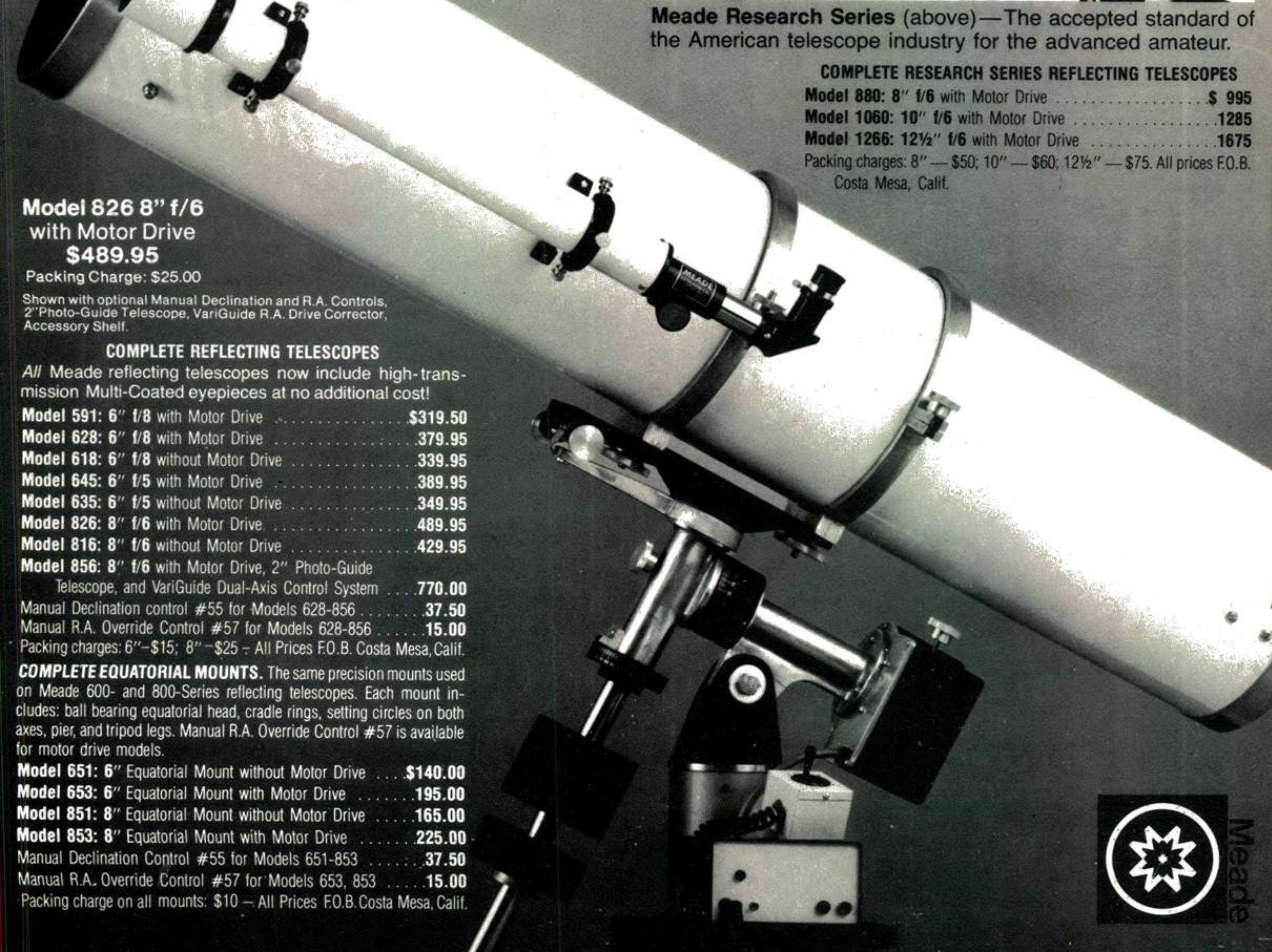

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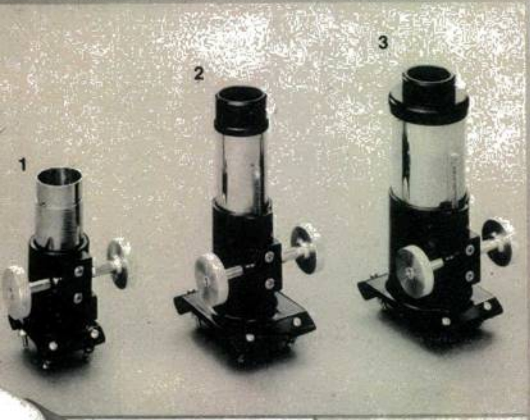

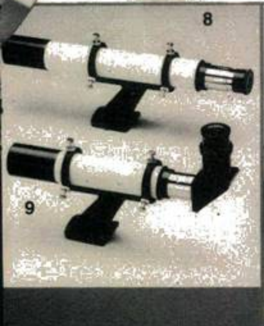

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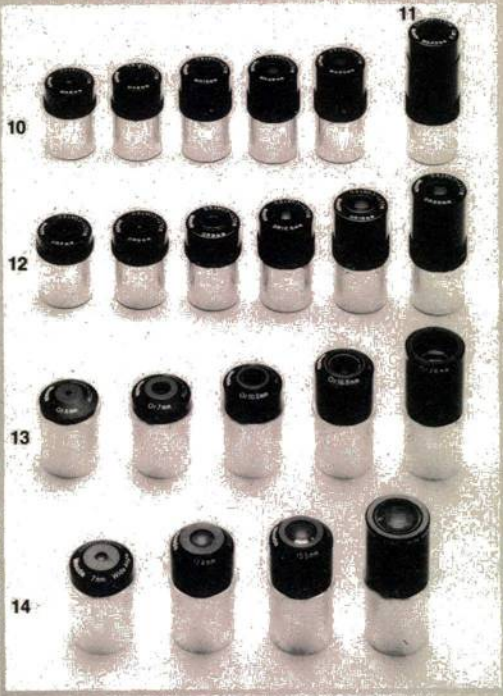

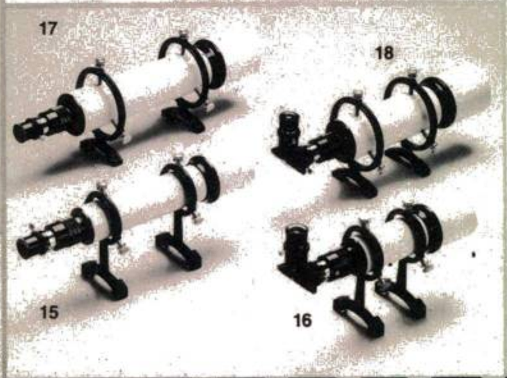

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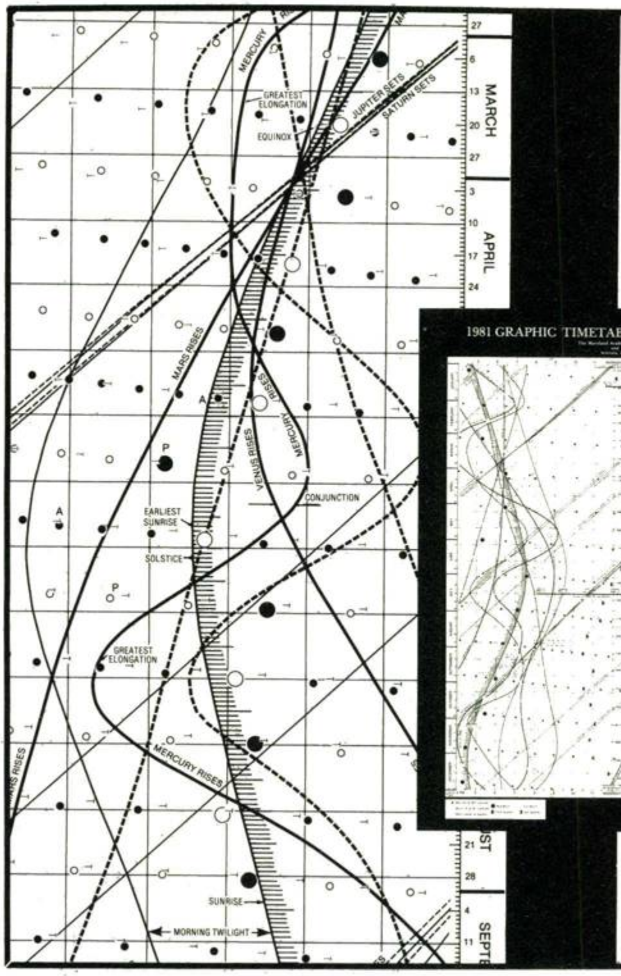

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Chances are that you began your astronomical hobby with a small refractor. Remember it? — a skinny white tube with chipped paint, missing a vital screw in the altitude adjuster, tiny eyepieces, thin tripod legs that never held it steady, and that useless 300x Barlow attachment. It might have revealed a universe to you — but you felt it wasn't a "real" telescope.

Yet refractors have traditionally been the instrument of choice for "serious" observers, extolled for their ability to pick out fine detail on the planets and split close double stars. Many old-time observers never exhausted the powers of a 4-inch or 6-inch refractor in their whole observing lifetimes. Where among the seeming contradictions does the truth lie?

Refractors focus starlight by bending the light rays, the lens acting like a prism. And, like a prism, all the rays are not bent equally, so that different colors of light come to focus different distances from the lens. Modern achromatic refractors use two types of glass in a "doublet" lens to correct about 95% of the color error a single lens has (see "What's Inside Your Telescope?", part 1, ASTRONOMY, March 1978). For large focal ratios (f/15 or thereabouts) and for small to medium apertures (under eight inches), the images from an achromatic refractor are nearly color-free.

Then, too, "bad seeing" caused by mixing air currents is less a problem with a closed refractor tube than it is with the open tube of a reflector (see "Cool Your Telescope," ASTRONOMY, February 1980). While a Newtonian may perform terribly for an hour or more after you take it outside to observe on a cool night, a refractor gives topnotch images right away.

Furthermore, refractor lenses stay in alignment. The lens cell is locked in place, so once adjusted may never need recollimation. Newtonians and catadioptrics frequently become misaligned, especially if roughly handled, and don't perform up to par.

Next, refractors are unobstructed. All Newtonians, all Schmidt-Cassegrains, and all Maksutovs have a secondary mirror that obscures (typically) the central 20 to 30% of the aperture. The light loss is not important, but the effect of a 30% obstruction on the image quality is the same as a ¼-wave error in the optical system: less light in the Airy disk and more light in the spurious rings. A refractor, with no obstruction, can produce a "perfect" image — but no obstructed system can. Only long-focus Newtonians with very small diagonals and tilted component telescopes (see "What's Inside Your Telescope?", part 4, ASTRONOMY, August 1978) can rival refractor images in this regard.

Finally, most refractors in use today have relatively small apertures — and are therefore affected by atmospheric turbulence less than "the competition," usually Newtonian reflectors. On a night of mediocre seeing, the small refractor may paradoxically give a steadier, sharper-seeming, and more psychologically satisfying image than a large telescope.

Thus, when you look through a small to medium refractor, you can expect the almost unbeatable combination of excellent images and reliable optical performance. What you won't get is the light-gathering power of a large aperture telescope — but then deep-sky observing is only one side of astronomy.

Remember there's a certain thrill in looking through a long, tall telescope (a telescope that *looks* like a telescope!) and showing your friends and neighbors the craters of the Moon, Jupiter's Red Spot, and the rings of Saturn. A 4-inch refractor is a good five feet long — and a 6-inch may exceed eight feet in length. If you're using a refractor, you can really get the feeling that you're doing astronomy the right way.

Why then do you, like most astronomy buffs, remember that first little refractor with less-than-total fondness? Was it really the optics that let you down — or was it the shaky budget-class mounting, poor eyepieces, undersized finder, and the focuser's habit of slo-o-o-o-wly sliding out all by itself? Did a light touch on the focus knob set off earthquakes in the image? Did tightening the clamp screw make the image leap to the left? Did you breathe a deep sigh of relief when you finally replaced it?

Chances are it was the mechanical problems in the mounting — not the optics — that disillusioned you. It wasn't the small size, for there is plenty to see and do even with a very small aperture. It wasn't the color correction, which is good in small refractors. It wasn't the objective lens (an excellent piece of glass) — but the cheap import eyepieces. Those mid-19th-century and turn-of-the-20th-century observers who spent their whole lives viewing the sky through a 4-inch refractor weren't crazy — they just had a good lens in a strong tube on a steady mount with a fine eyepiece — and the skill, the time, the persistence, and the dark skies to put it to full use.

Since the era of the cheaply-made and inexpensive imported refractors has drawn to a close, driven by the falling value of the dollar relative to the yen, and perhaps more importantly by the demand for quality equipment, refractors nowadays are not inexpensive. For the price of a 4-inch refractor, you can buy an 8-inch catadioptric, a 12-inch Newtonian, or build a 17-inch Dobsonian and have money left over — but the joys of using a fine refractor will never fade.

— *Richard Berry*

ASTRONOMY REVIEWS

Geophysics of Mars
R. A. Wells
678 pages, hardcover, $87.75
Elsevier (1979)

Original scientific reports, in a field such as Mars research, are written for fellow researchers and are scattered among many technical journals. Readers outside of the field who want more information will likely get lost finding and understanding these papers. Between the original reports and popular articles lie review papers and texts. Ideally, reviews assemble the scattered literature into detailed summaries and analyses of often conflicting theories. Authors of such books should play fair when weighing various theories, especially their own.

Wells' *Geophysics of Mars* aims to present an overview of observations of Mars from Earth and pre-Viking missions to the red planet. Added at the end is a chapter summarizing the initial results of the Viking Project.

The book is written around two major themes. The first is the interpretation of observations of Mars' variable appearance in terms of an atmosphere filled with ice crystal and mineral dust hazes. The second theme is an interpretation of the geology and topography of Mars using a model of internal convection and crustal motion inferred from the planet's gravity field.

In his introduction, the author states: "Both themes have never been pursued in any detail elsewhere; consequently, they constitute significant departures from current interpretations." His first point is correct; the second is an understatement. Many of Wells' opinions are radically different from current interpretations of Mars.

Chapter one reviews in detail the painfully slow determination of the mass, composition, and structure of Mars' atmosphere. Its second half reviews decades of Earth-based studies of martian clouds and their seasonal behavior. I know of no other good review of this unique information. Spacecraft observations of Mars have not yet provided continuous, global observations of martian weather.

Chapter two, almost a third of the book, presents Wells' unconventional views on the "blue haze" and seasonal darkening. He argues that the normal invisibility of light and dark surface features in violet photos, and seasonal changes of these areas, can be explained by the presence of mineral dust grains much smaller than the wavelengths of light in Mars' atmosphere. In Wells' hypothesis, using the Mie theory of light scattering, the dust tends to scatter blue light back toward Earth, obscuring the martian surface. Seasonal changes are then due to seasonal clearing of this dust alternately from northern and southern hemispheres.

Accepted theory, supported by results of the Viking missions, explains the low contrast of Mars in blue pictures by a combination of low contrast between some dark and light surface regions at blue wavelengths, and hazes of large dust particles and thin ice clouds. Seasonal changes are believed to result from semiregular deposition of dust over large areas during annual dust storms, followed by the wind stripping the dust from dark regions. Seasonal variations in cloudiness also occur.

The next three chapters review the spectacular terrain features of Mars, its global topography, and imaginary (canal) and real (tectonic) linear patterns. Much of these chapters consists of summaries of many scientists' results, but some of Wells' own work is included.

Chapter seven lays bare the core of the differences between Wells' view of Mars and that of most researchers. He believes that the mantle of Mars has been convecting slowly since the formation of the planet, and that a core has been growing at its center slowly with time. Initially, he claims, rising motions created the great Alba Patera volcano, while sinking currents formed the Hellas basin in the south. Then the circulation pattern changed to rising currents at the equator and sinking ones at the poles.

The great canyons of the Valles Marineris, he thinks, were formed by crustal spreading, while the spectacular layered deposits found at both poles would have formed by downwarping and compression of the surface. None of this has found general acceptance.

Most researchers believe today that there has been convection in Mars' mantle which drove the tectonics that warped the crust into the great Tharsis uplift, produced the volcanic activity that inundated the northern third of Mars with lava flows, and built the great volcanos.

But the Alba volcano is known to be relatively young, while Hellas is the largest asteroid impact basin on Mars and is very old. The Valles Marineris seem to have formed along faults in the crust split by the bulge of Tharsis. The polar terrain is thought to be the results of millions of years' deposition and erosion of vast deposits of dust and ice. The evidence supports these theories more and better than it does Wells' theories.

Which brings up an important point: tolerance of unusual, minority opinions is one measure of the health of a scientific field. Anybody's theories are fair game; the test is how well they fit what we see. By this criterion, Velikovsky's theories have been tried and found wanting. (On the other hand, the suppression of his theories in 1950 will forever be a black mark in planetary astronomy.)

Ronald A. Wells has shown courage

and determination in attacking accepted theories and in presenting his own, and Elsevier Press has shown courage and tolerance in publishing them. While I believe that he is wrong, he has a right to be heard and to defend himself. Let the fray begin.

Because of the controversial nature of Wells' theories, the technical detail of the book, and its cost ($87.75), I can't recommend it as an introduction to Mars. But readers who don't mind working hard, and are dissatisfied with standard theories, should find food for thought. Caveat emptor! *Edwin Strickland.*

Fujichrome 400

20 & 36 exposure rolls
Fuji Photo Film USA, Inc.

The latest Japanese invasion in the photo field, Fujichrome 400 color slide film, will probably not send Kodak scurrying for cover behind ramparts of yellow boxes, but it does seem likely that the new film will nonetheless attract an enthusiastic following among deep-sky photographers.

For accurate and brilliant rendering of the hard-to-capture colors in nebulae, galaxies, and star clusters, no single color film can yet compare with the demanding color separation process where three individual black-and-white photos of an object, taken in filtered light of different colors, are combined to produce one color photo. Color films sensitive enough for deep-sky work all suffer, to one degree or another, from inaccurate color balance at low light levels. They also tend to be grainy and to yield "soft" and low-contrast images.

While the new Fujichrome 400 is not the final answer by any means, a brief tryout of the film under clear Arizona skies with a 14-inch Schmidt-Cassegrain telescope suggests that the film is very fast under deep-sky light levels. (This permits tolerably short exposure times without need for a cold camera.) The film renders star colors brilliantly and glowingly, and is free of the greenish sky background that often plagues Kodak's Ektachromes.

Fujichrome 400 and the equivalent 400 ASA Ektachrome were compared, for "existing light" snapshot uses, in a recent issue of *Popular Photography* (September 1980). According to them, Fujichrome had a slight edge over Ektachrome in freedom from grain, and was superior in rendering the red end of the spectrum. For deep-sky work (like its fine-grained cousin, Fujichrome 100), Fuji 400's reciprocity failure weakens its response in the blue-green region of the spectrum. This tends to suppress the skyglow that can be so troublesome in Ektachromes and Kodacolors. Yet its failure is limited: blue stars and blue reflection nebulae look blue on the film.

I took test exposures with Fujichrome 400 that had been hypersensitized in forming gas (92% nitrogen; 8% hydrogen) for 1½ days at 30° C (86° F) at a pressure of 9 p.s.i. Although this was probably only a half to a third of the maximum practical hypersensitizing time (and was therefore limited in its effect), color balance, speed, and background fog were superior to hypersensitized Fujichrome 100.

Exposed at f/5.5 in the 14" telescope, the new film captured the three-dimensional effect of the Trifid Nebula, usually seen only in photos with larger telescopes, and did so with an exposure of only 20 minutes. 15 minutes' exposure captures not only the Ring Nebula's subtle color shadings, but also the nebula's 15th magnitude central star and another star within the ring. 45 minutes' exposure reveals the ghostly red outline of the Helix Nebula — and that long exposure didn't bring up significant sky fog despite the Helix's far southern declination.

The availability of Fujichrome 400 may be a problem in some parts of the country: it was rather hard to find in New York City camera stores in October 1980. Astrophotographers should write or call Fuji Photo Film USA, Inc., 350 Fifth Avenue, New York, NY (telephone: (212) 736-3335) for sources. Development via the E-6 process can be done by Fuji authorized labs by mail, or by other independent laboratories. Also ask Fuji for the Film Data Sheet for Fujichrome 400 RH, which I suspect will tell you somewhat more than you want to know about this promising new deep-sky film. *David Healy.*

The Radiant Universe

Michael Marten & John Chesterman
128 pages, hardcover, $17.95
Macmillan Publishing Co. (1980)

Electronic remote sensing and data processing of images have become so commonplace in astronomy and space science that it's a little startling to remember that it hardly existed 20 years ago. Even 10 years ago, multiband spectral sensing was in its early development. And perhaps even more startling is how much information we can now wring out of an image with a little careful "massaging of the data."

Marten and Chesterman's colorful book starts with galaxies — and shows what processing reveals: their faint, tenuous, outer reaches and important features hidden in the blaze of light at their centers. Next, the Sun's dynamic surface and atmosphere yield secrets unsuspected before instruments were carried above the Earth's obscuring atmosphere. The Moon, Mars, Mercury, Jupiter & its satellites, and comets are covered in the third section. The fourth and last section deals with terrestrial remote sensing.

Recent Developments in Gravitation

Maurice Levy & S. Deser, eds.
596 pages, hardcover, $69.50
Plenum Press (1980)

Not for the mathematically squeamish, this is the record of papers given at a 1978 NATO Summer Institute held in Cargese, Corsica. The 16 papers are arranged in three sections: classical relativity, quantum gravity, and supergravity.

The Physics of the Interstellar Medium

J.E. Dyson & D.A. Williams
194 pages, hardcover, $24.95
John Wiley & Sons (1980)

A substance about which little was known 50 years ago, the interstellar medium — that agglomeration of gas, dust, and plasma — has taken on prime astrophysical importance. Why? We now know that out of it came many of the stars we see as well as the solar system we inhabit .

This volume (written at a professional level) covers what the material is, how we learn about it, and how it behaves on microcosmic and macrocosmic scales.

The Quest for Extraterrestrial Life: a book of readings

Donald Goldsmith
308 pages, hardcover, $18; paperback, $12
University Science Books (1980)

No one's yet found it, but that's not for lack of trying — as this very enjoyable anthology attests. The book explores its subject with 58 reprinted articles and book excerpts grouped into five major topics.

First, "historical perspectives" (which has selections from Lucretius to Voltaire), then "the origins of life" (with biologists, starting at Darwin). "The search for life in the solar system" (Lowell to the Viking Project) follows, with "intelligent life outside the solar system" (Cocconi & Morrison to Bracewell) next.

"Optimists and pessimists" gives a soapbox to scientists who proceed to thrash out their opinions on Yes, We Are Alone or No, We're Not. Lastly comes "bread on the waters," which tells of our attempts, via the Arecibo Radio Telescope and the Pioneer and Voyager spacecraft, to contact Them.

STAR & SKY

HAWAII/ ECLIPSE CRUISE

Sail into the path of totality -in the North Pacific- on July 30, 1981!

On February 26, 1979, millions of Americans watched as the moon's disc covered the sun, producing nature's superspectacular – a total solar eclipse. But the celestial clockwork has ordained that America will not be placed under the moon's shadow again for 36 years. Last year eclipse-chasers travelled to Africa and India to see the spectacle. Since total solar eclipses can be witnessed somewhere on Earth about once a year, we decided to sail into the path of totality in the North Pacific on July 30th.

Be among the special group of people who will view a total solar eclipse from the decks of a 30,000-ton 682-foot luxury liner at sea. ***Star & Sky Expeditions*** has contracted the SS Oceanic Independence, of American registry, for the sole purpose of seeking the awesome darkness at midday.

The 14-day cruise includes the voyage to and from the eclipse site, approximately 1200 miles northwest of Honolulu. ***This location has better than an 80% chance of clear skies*** – *SUBSTANTIALLY BETTER THAN ANY OTHER LOCATION ALONG THE PATH OF TOTALITY.*

The eclipse-viewing will be followed by a ***5-day Hawaiian Island cruise,*** making ports-of-call on the islands of Kauai, Maui, Hawaii, and Oahu.

Our scientific staff is the finest ever assembled for an eclipse cruise: ***Bart Bok,*** formerly professor of physics, Univ. of Ariz., and director, Steward Observatory. ***John Eddy,*** senior scientist, High Altitude Observatory, Boulder, Colo., and solar expert and author. ***William J. Kaufmann,*** adjunct professor of physics, San Diego University, and author of nine books on astronomy and relativity. ***James Sadler,*** head meteorologist, Univ. of Hawaii. ***George Keene,*** senior engineer, Eastman Kodak, and astrophotography expert. ***Terence Dickinson,*** editor, ***Star & Sky***. Our cruise director is ***Robert T. Little,*** Field Sales Manager for Criterion Scientific Instruments, veteran of three eclipse cruises and seven Astronomy Island cruises to Bermuda, pioneer of solar-eclipse photography at sea.

Space for this incredible eclipse cruise is limited so you must act now. Prices start at $2,000 per person, double occupancy, plus airfare. Detailed information is available in our brochure which can be obtained, along with a free copy of our 1980 eclipse issue, by writing to:

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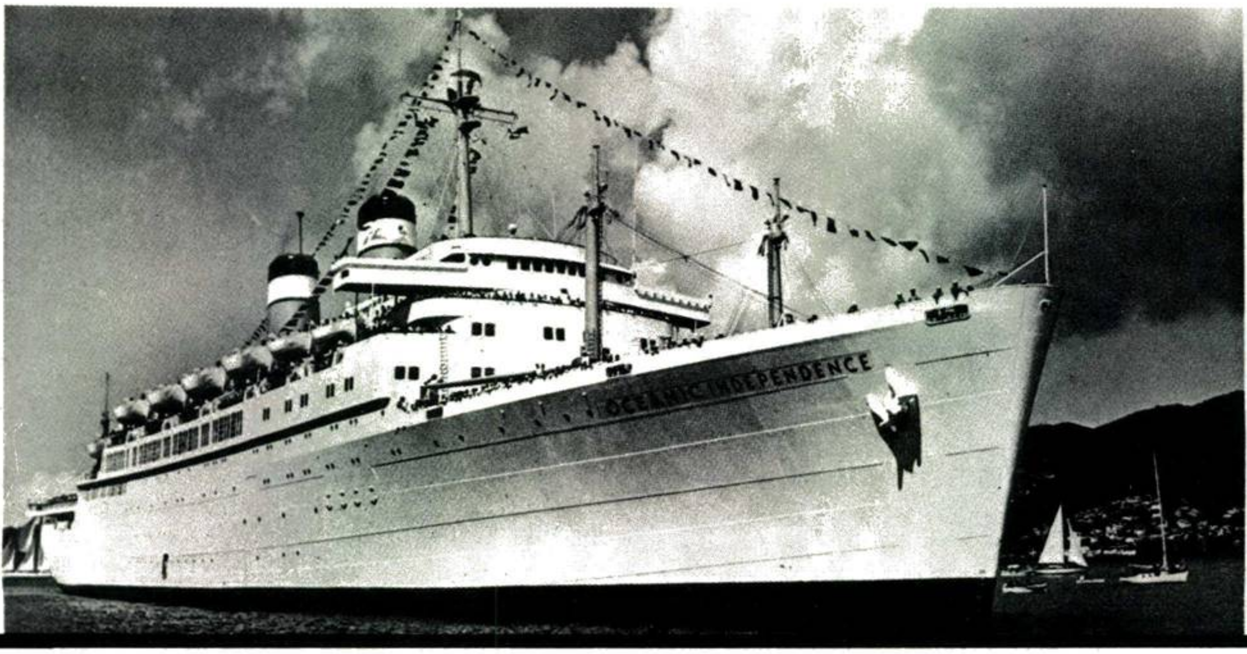

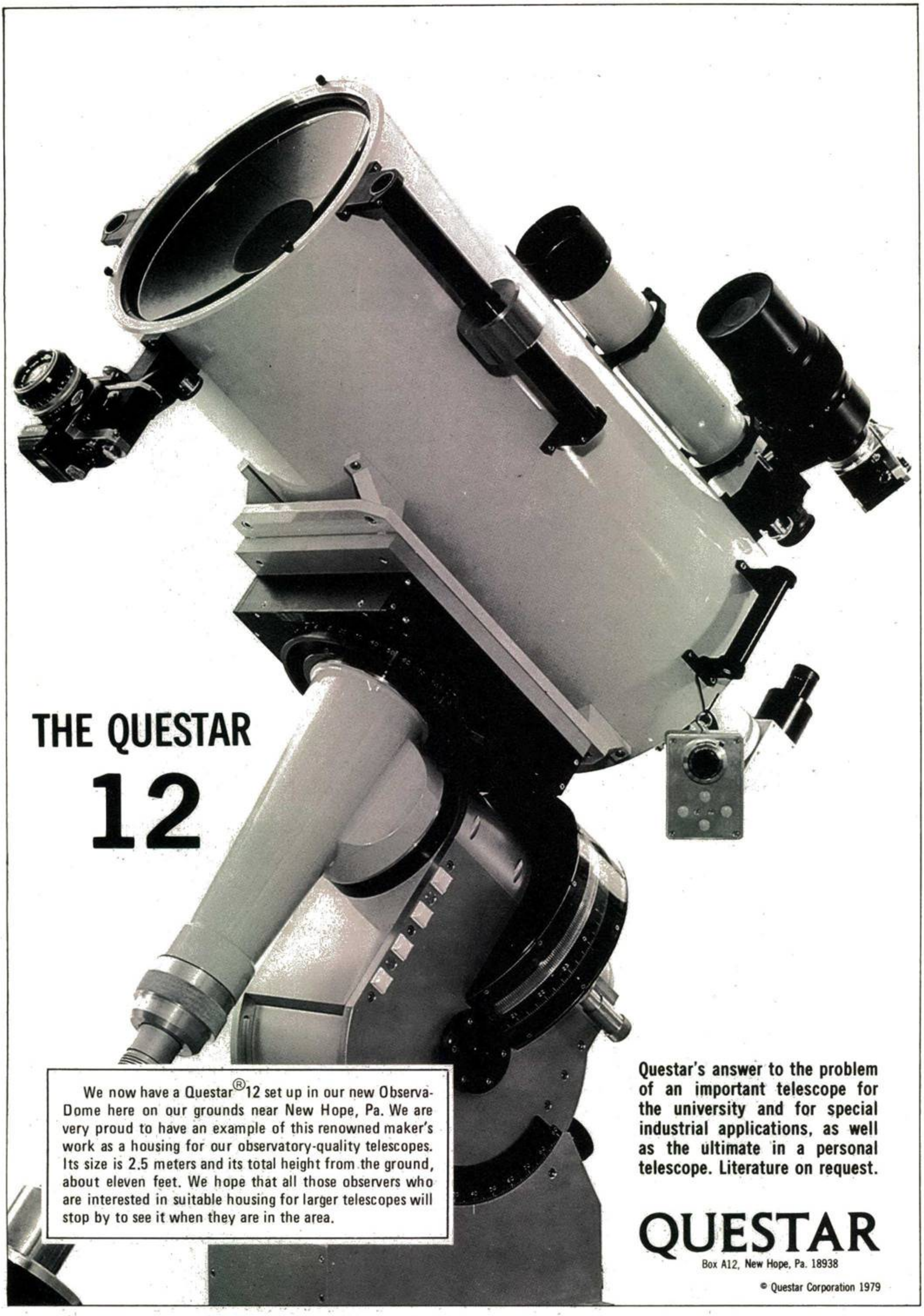

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photography
in
astronomy

"bare-bones" astrophotography

Getting started in astrophotography may be a lot easier than you think. There's no need for fancy equipment (guiders, clock drives, eyepiece projection systems); you don't even have to have a telescope. All you really need are a camera, some film, and a tripod.

Camera. Virtually any will do, though a couple are hopeless (110 Instamatics, for example). Look for the following: ability to take time exposures, a lens that focuses to infinity, and a wide-aperture (numerically low f/ratio) lens.

Time exposures are necessary because they allow light to store up an impression in the film. See if the camera's shutter includes a setting called "B" or "T". On B (for "bulb"), the shutter remains open for as long as you press the shutter button; when you let go, the shutter closes. With T (for "time"), you trip the shutter once to open the lens and a second time to close it.

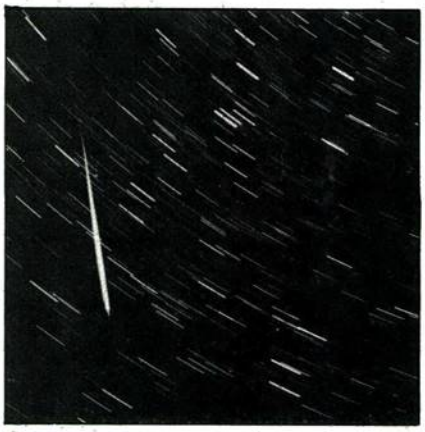
Focus is just as important as time exposure because the heavens lie "infinitely" far away and must be imaged sharply. Fortunately, nearly every camera on the market that has an adjustable focus can be set to infinity. What should you look for? Low to medium-priced cameras usually have three symbols on the lens barrel: one person's head and shoulders, two or three people in a group, and a couple of mountains. The last setting is your infinity focus. Medium to expensive cameras often show the mathematician's infinity symbol (∞).

The last requirement — low f/ratio — is less urgent, though still pretty important. Low f/ratio lenses let in more light so your exposure time can be shorter and you can record fainter stars in less time.

It's becoming hard to find a "normal" (50 mm focal length) lens for 35 mm cameras these days slower than f/2.8 and the norm lies up around f/1.4, fully two stops faster. For telephoto and wide-angle lenses — as well as for formats larger than 35 mm — the usual f/ratio is slower. Use the fastest lens you can.

Tripod. The watchword is to buy the best you can afford. There are a great many spindle-shanked, rickety models on the market — avoid them! A tripod should hold your camera steady; a wiggly one never will. A good test is to extend the legs fully and crank up the head to its highest position. Place your hand where the camera will go and give the tripod a shake while you push down on it. Does it wiggle or squirm? If it did, put it aside and keep on looking.

Don't be misled by flashy details — fancy leg tips that instantly convert from rubber balls to spikes, or heads you can crank up, down, and pan sideways. Remember a tripod must be stable. Get one that is and you'll find the other features are satisfactory, too. (But be prepared to pay $50 to $100.)

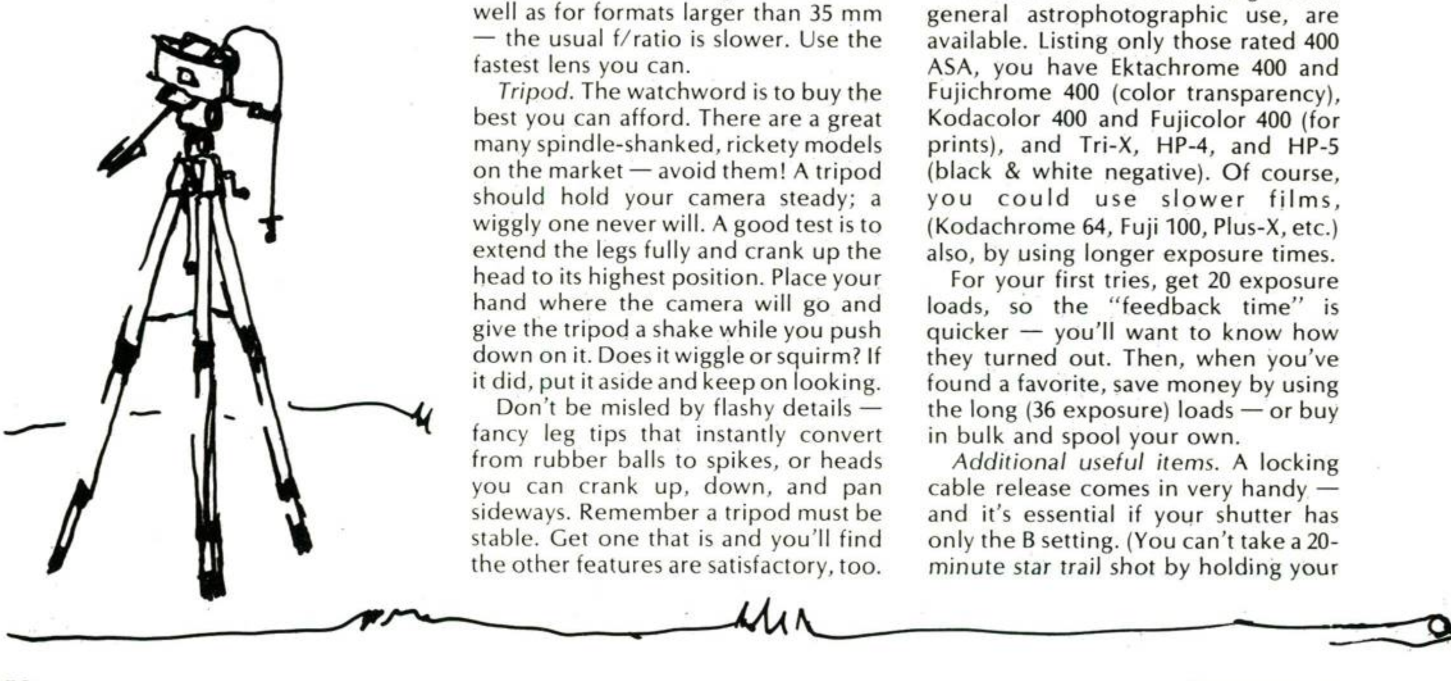

Perseid meteor photo by Scott Patterson

If you're stuck with one that's not very good, try tying small sandbags to it (made from old socks). Or hang a weight like a full bookbag between its extended legs. This will damp out some vibration and add a considerable measure of stability.

Film. Several fine fast films, good for general astrophotographic use, are available. Listing only those rated 400 ASA, you have Ektachrome 400 and Fujichrome 400 (color transparency), Kodacolor 400 and Fujicolor 400 (for prints), and Tri-X, HP-4, and HP-5 (black & white negative). Of course, you could use slower films, (Kodachrome 64, Fuji 100, Plus-X, etc.) also, by using longer exposure times.

For your first tries, get 20 exposure loads, so the "feedback time" is quicker — you'll want to know how they turned out. Then, when you've found a favorite, save money by using the long (36 exposure) loads — or buy in bulk and spool your own.

Additional useful items. A locking cable release comes in very handy — and it's essential if your shutter has only the B setting. (You can't take a 20-minute star trail shot by holding your



thumb on the button all the while.) Cable releases also control vibration by keeping your hands off the camera.

Lens shades, too, come in handy for helping to keep stray light — from a neighbor's porch or an unavoidable streetlamp — from fogging your shots.

A piece of black cardboard or even construction paper makes a basic "shutter." When you are ready to expose, open the camera's shutter while you hold the cardboard in front of the lens. After a few seconds, when all vibrations have died out, flick the cardboard away to start the shot. Recover the lens and close the shutter in reverse order when you've finished.

So much for equipment — what can you photograph?

Star trails. These are the simplest of all astrophotos to take. Just point your camera at the sky and shoot. Aiming it at the north pole and exposing for longer than a minute or two will produce a set of star trails arcing concentric to Polaris. A closer look at the film shows that even Polaris records as a short trail — reminding you that the "pole star" really isn't at the true pole.

If you shoot from an urban location with fast film, you'll soon find that 30 seconds to 10 minutes is about the longest you can expose before the bright sky blots out the faint star trails. Suburban skies are better, giving runs of 10 to 40 minutes before fogging takes over. Dark rural skies allow exposures of several hours.

Meteors. If you've been lucky, you may find a meteor streak among your star trails. Look for a line that begins gradually, grows brighter, perhaps with a flare or two, and then dies out relatively abruptly. Almost always, it cuts at an angle to the star trails.

But trying to photograph meteors deliberately can be frustrating. Just as with visual observations, the best times are during one of the annual showers — the Perseid, the Geminid, etc. Look up the shower's radiant point (the point on the sky they appear to come from) in Through the Eyepiece and point your camera about 45° away. Forty-five degrees is the trade-off point between getting a good, recordable streak and having the meteors spread out over too much sky.

Despite their generally slower f/ratios, wide-angle lenses work best: a 28 mm lens covers nearly four times as much sky as a 50 mm lens. Even so, don't be disappointed if your first roll catches only one or two meteors — that's about average since you see many more than record on film.

Conjunctions. The proximity of Jupiter to Saturn this year has made people aware of groupings of stars, planets, and the Moon. These groupings, called *conjunctions* by astronomers, are very easy to photograph.

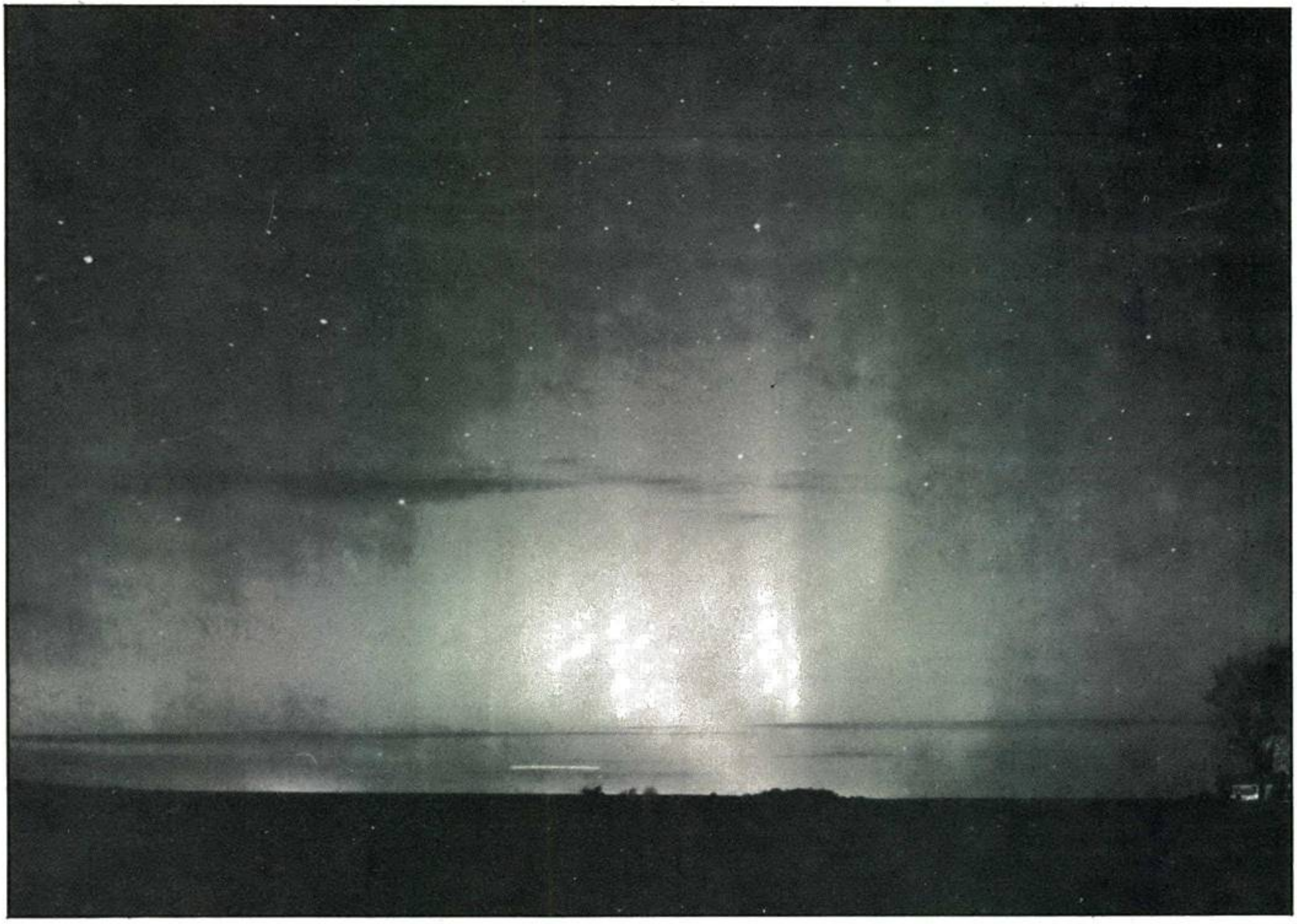
The ideal lens focal length to use will vary depending on the number of objects involved and how close they are. For example, the array of four planets in the morning sky last November 20th (see page 34) was shot best with normal or wide-angle lenses. But a series showing Jupiter's motion relative to Saturn, say, might come out best with a medium telephoto. (Read the box to learn how to work out the lens focal length you need to include a given spread of objects.)

If you can, include some foreground objects (houses, trees) in your photos as this sets the scene for your viewers — not all of whom may be astronomically knowledgeable. (You'll also find this moves an ordinary shot into the "show-stopper" class.)

Look closely and you'll see the stars of Cassiopeia rising over the trees in this 15-minute exposure by Richard Hunt.

Aurorae. Being prepared is essential, but being in the right place at the right time counts a lot, too. Even if you live downtown in a big city, take a look to the north every clear night; curtains, rays, or just a shapeless glow that isn't city light pollution may indicate some auroral activity. Really good displays are rare, but when they light up, you'll want a wide-angle lens and fast film.

Short exposures (5 to 15 seconds) will capture the brightest structures pretty well, but you won't record very many. Longer exposures (15 seconds



Tom Harris shot this aurora with a 30-second exposure. (The bright streak along the horizon at center is an airplane.)

to a few minutes) will pick up more structures and color, but because the features are usually moving, blurred details are almost guaranteed. Best bet: take a series with varying exposure times.

Scenic shots. Lastly, don't overlook the "pretty picture." Sometimes a great astrophoto shows nothing more than some trees, twilight, and a crescent Moon glowing with earthshine. It could be a time-exposure "snapshot" in the still waters of a lake. Or maybe it's Venus, glinting across a rocky snowfield on a mountainside. The where and what don't really matter. You've looked; you've *seen* great photos. Now, go take them.

— *Robert Burnham*

how big is that on film?

Since an object's angular size, the lens focal length, and the object's resulting size on film are all interrelated, once you know any two of the three quantities, you can easily work out the third.

For example, suppose you want to know how large the Moon (angular size: 32′ or 0.5°) will appear on film when shot with a 200 mm telephoto lens. Use the following formula:

$$S = A \times F / 57.3$$

where S is the size on the film, A is the object's angular size in degrees, and F is the lens focal length. In the given example, the Moon's image will be 0.5 x 200 / 57.3 = 1.8 mm in diameter.

Or let's say you want an image of the Moon on the negative to be ¾″ in diameter. How long a lens do you need? Use:

$$F = S \times 57.3 / A$$

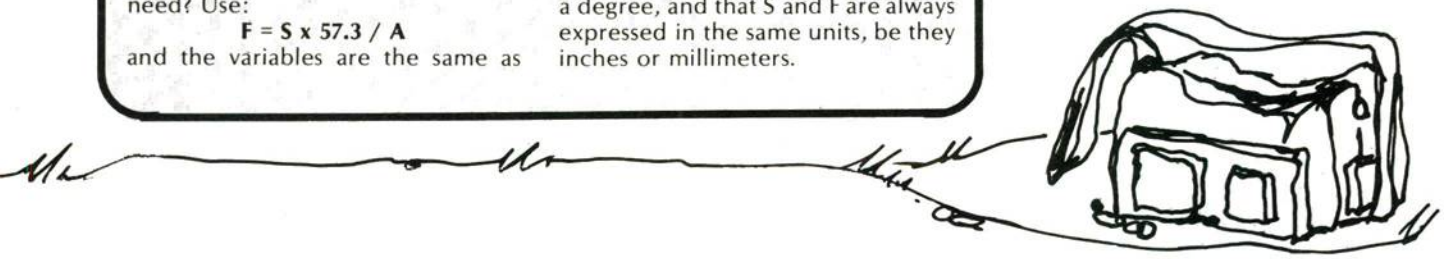
and the variables are the same as before. Three-quarters times 57.3 divided by 0.5 equals 85.95 inches of focal length, or in metric units, about 2200 mm.

Now let's suppose you want to know how wide a field of view you get with a given lens and film format. What's the field of view of a 28 mm lens on 35 mm film? (A 35 mm frame measures 24 mm by 36 mm.) Use:

$$A = S \times 57.3 / F$$

A, in this case, refers to the field of view, but could also be the unknown angular size of an object photographed. Working out the numbers, we get a field of view 49° by 74°. (24 x 57.3 / 28 = 49.1 and 36 x 57.3 / 28 = 73.7)

Remember that A is always measured in degrees and decimals of a degree, and that S and F are always expressed in the same units, be they inches or millimeters.



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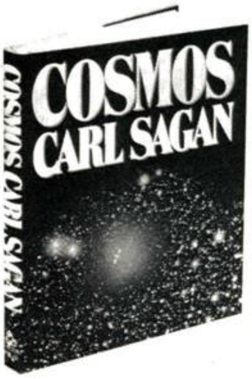

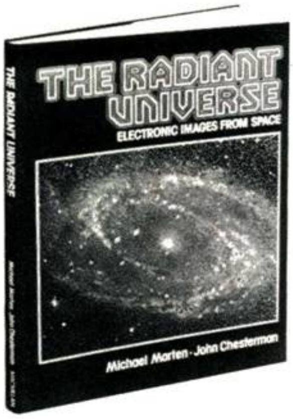
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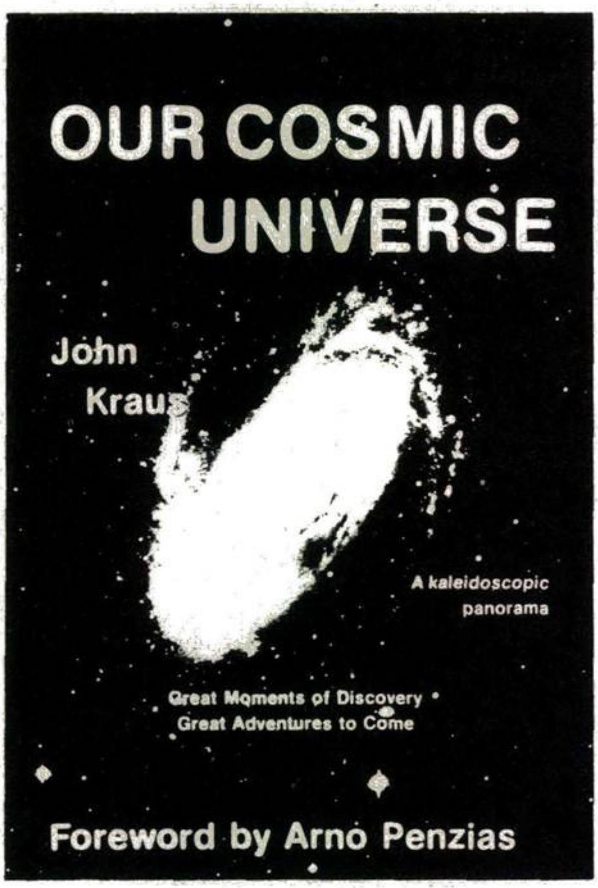

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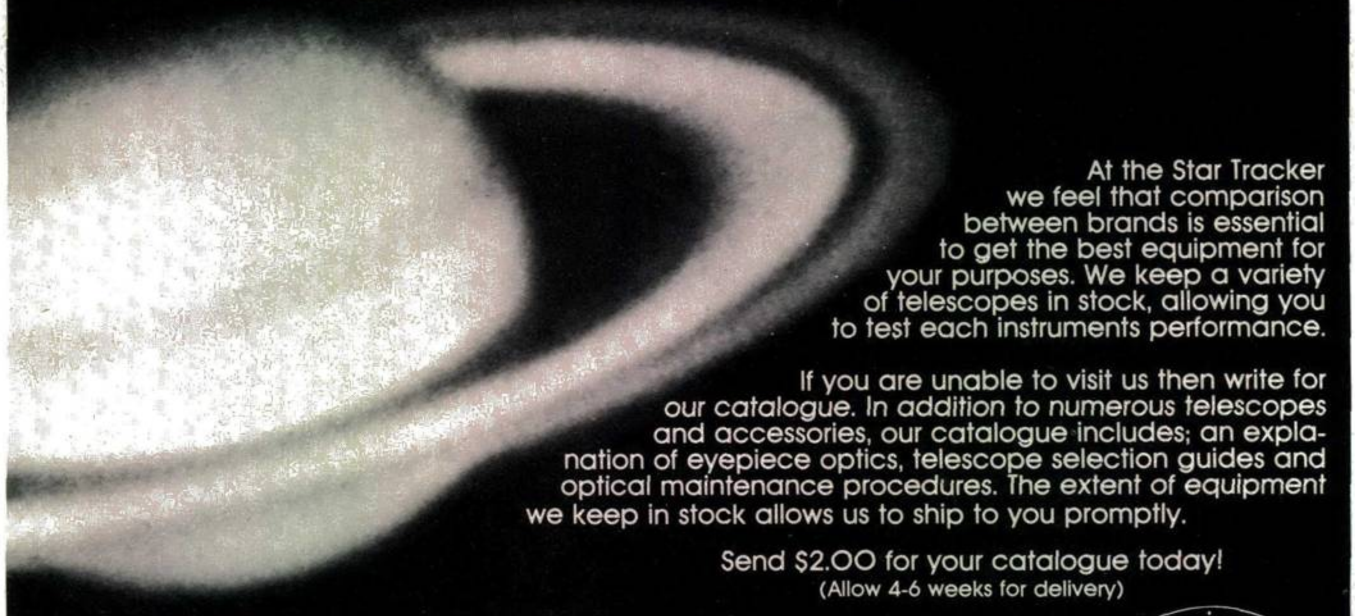

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AstroNews

Pioneer Venus 1 Completes Two Years in Orbit

On December 4, 1978, a spacecraft was placed in orbit around Venus to study the cloud-shrouded planet while a sister craft deployed five separate probes into the atmosphere a few days later. The orbiter, Pioneer Venus 1, is still functioning well and is expected to remain in Venus orbit until 1992, and NASA has announced an extension of its mission through 1986.

To mark the second anniversary (equivalent to three full days on Venus) of the extremely successful Pioneer Venus Orbiter, NASA held a news conference at the Ames Research Center in Mountain View, California, where the Pioneer Venus project is headquartered. Completion of detailed analysis of data from the Orbiter and the atmospheric probes resulted in a number of new findings which were announced at the press briefing.

One of these findings was an explanation for the planetwide circulation of Venus' entire atmosphere, which represents the first real scientific understanding of the overall "weather pattern" of Venus. While the cloud tops circle the planet once every four days, the dense, massive atmosphere closer to the surface travels much more slowly. Solar radiation absorbed by the clouds, chiefly close to the equator, constitutes the energy source for the atmospheric circulation. The heated atmosphere then moves slowly toward the poles as well as rapidly around the planet in a continuing spiral away from the equatorial region. Once the heated atmosphere reaches the poles, it descends via the polar vortices and other mechanisms toward the surface, where it returns to the equator to be recycled again.

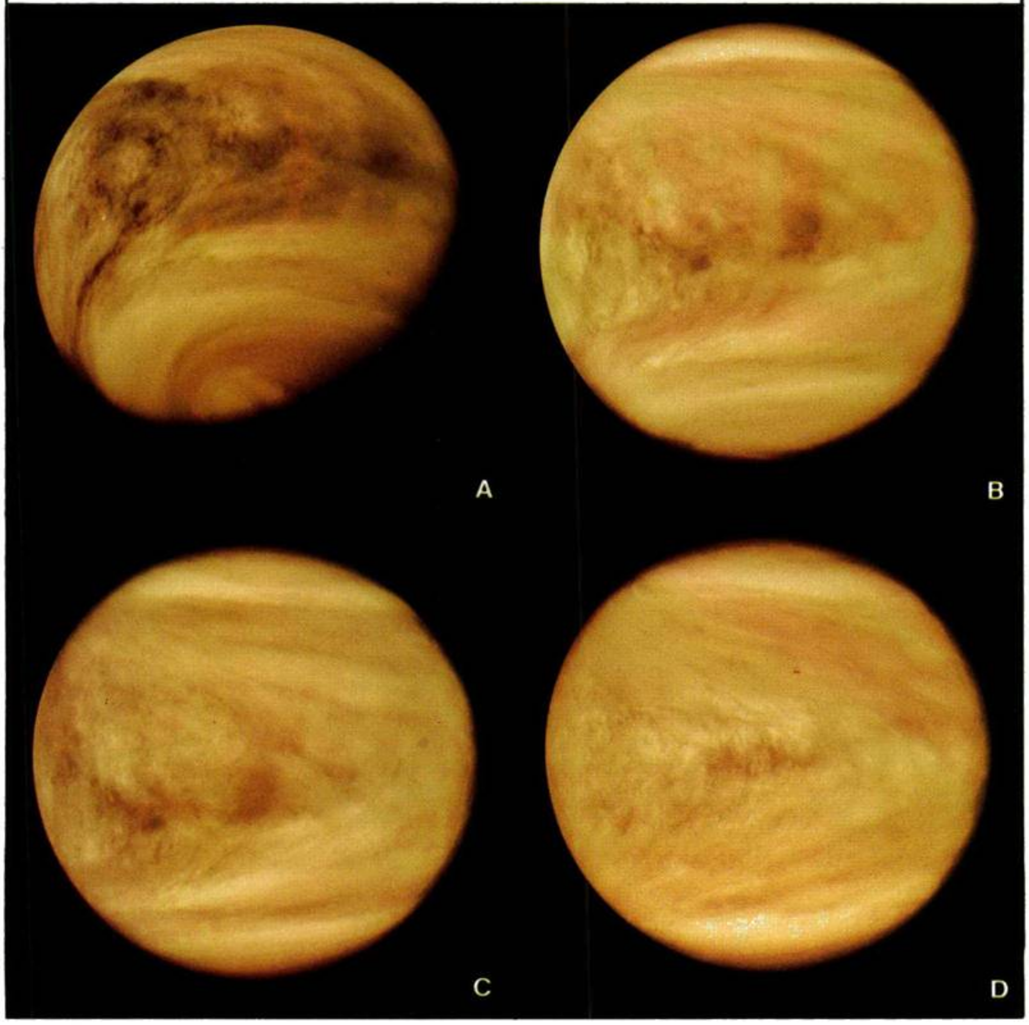
Because of this vigorous, planetwide circulation, Venus' atmosphere is heated evenly at the equator and poles and on both the day and night sides, so there is little temperature variation with either longitude or latitude. Everywhere on Venus, the temperature remains steady at about 900° Fahrenheit, with atmospheric pressures 90 times greater than at sea level on Earth.

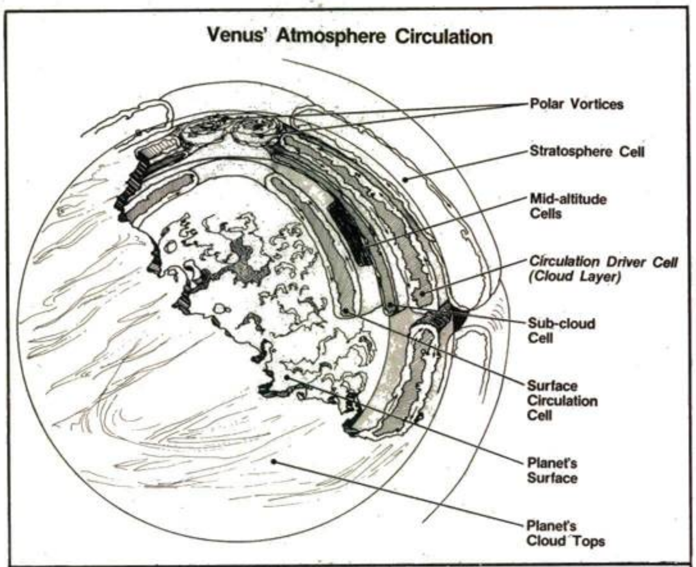
The principal energy absorber and driver for this equator-to-pole circulation is Venus' dense cloud region. Other equator-to-pole circulation cells in the planet's lower atmosphere and stratosphere are driven by the main circulation cell made up of Venus' clouds. One surprise was the extreme stability of the lower atmosphere, with very little overturning and mixing, though there is evidence for eddies in the region within 30° of the equator.

NASA scientists also announced that further new work now seems to explain the working of Venus' "greenhouse effect" (which produces the planet's searing heat). Originally it was thought that such a greenhouse effect, produced when more solar radiation is absorbed than is re-radiated by the atmosphere, was insufficient to account for the extremely high temperatures measured. Now, however, mathematical modeling on the basis of the known constituents and dynamics of the planet's atmosphere accounts fully for the observed heat. Carbon dioxide is responsible for 70% of the effect, water vapor contributes 15%, and the rest is due to a combination of sulfur dioxide and cloud particles.

Since its arrival at Venus, Pioneer has returned over 1000 ultraviolet pictures of

These ultraviolet photos of Venus' clouds have been selected to show a variety of cloud formations. Taken by the Pioneer Venus Orbiter between May 2 and 4, 1980, they cover a period of 38 hours. In time sequence the pictures were taken as follows: (A) May 2, 1980, 7:58 a.m. PDT; (B) 9½ hours later; (C) 14 hours later; (D) 38 hours later. The planet's clouds circle Venus completely every four days. NASA photos.





Solar energy is absorbed in the clouds of Venus which constitute the circulation driver cell. This cell extends from the equator to the poles and then cycles back to the equator. The cloud circulation driver cell drives the other circulation cells shown here, mixing Venus' atmosphere thoroughly. NASA diagram.

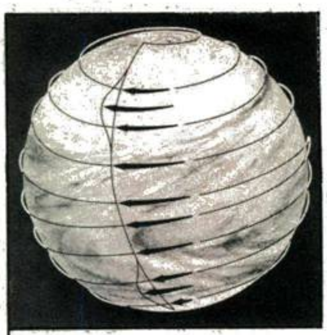
Venus' clouds, and has mapped by radar 93% of the planet's surface, revealing a terrain of mountains, high plateaus, and great plains. (See lead feature in this issue.) Over 40 billion bits of data have been transmitted by Pioneer back to Earth. The spacecraft gamma ray instrument has recorded 75 gamma ray bursts from various parts of the Galaxy, and Pioneer's other 17 instruments have made a variety of measurements of Venus' atmosphere and surface, its interior, and the surrounding environment.

Over the next six years, the Pioneer Orbiter will be looking at Venus from a variety of new vantage points. For the first two years of its mission, maneuvers commanded from Earth have maintained the spacecraft orbit in one fixed position relative to the planet. From now on Pioneer's orbit will instead be allowed to "float," responding to pressure from solar radiation and the gravitation of Venus and the Sun.

This means that the orbit, formerly tilted 17° to the equator, will drift down until it coincides with Venus' equator in 1986. This also means that its orbital low point will rise from 150 kilometers (93 miles) above the planet's surface in 1980 to 2200 km (1365 miles) above it in 1986. After 1986, the orbital low point will reverse direction, dropping downward again until it is so low that the spacecraft enters the atmosphere and burns up in 1992. By that time the orbital tilt will have returned to 17° to the equator, but the orbital low point will be in the southern rather than the northern hemisphere.

As Pioneer's orbit changes position during this "float" period, it will be possible to measure the planet's bow shock wave and wake region or "tail" in the solar wind and other planet-solar wind interactions at a variety of places not now reachable by the spacecraft. Gravity-sensing experiments will be improved because the small rocket thrusts made to maintain spacecraft position will no longer be needed. It should be possible by this gravity sensing to make detailed and precise maps of mass concentrations in Venus' crust.

Virtually all other instruments (except the radar mapper — which is to be turned off this month) can continue making their measurements, providing a longer time to study such things as periodic long-term changes in cloud circulation. Other instruments will be able to study planet-solar interactions during a large portion of a solar cycle, and perhaps even through a complete cycle. There should be significant changes in Venus' upper atmosphere as the Sun comes down from its present period of high activity.



Venus' atmosphere circles the planet once every four days at the cloud tops, at the same time spiraling slowly toward the poles away from the equator. NASA diagram.

Cooperative measurements may take place with Russian Venus spacecraft, expected to arrive at the planet in 1982 and 1984.

Other ASTRONOMY articles dealing with the current exploration of Venus are:

"Rendezvous with Venus," AstroNews, December 1978.

"Venus Mission a Success!" AstroNews, February 1979.

"Pioneer Venus: First Results," April 1979.

"More Pioneer Venus Findings Announced," AstroNews, July 1979.

"Venus and Earth: Engaged or Divorced?" AstroNews, October 1979.

"Alien Eyes," January 1980.

"The Surface of Venus from Pioneer," AstroNews, August 1980.

"Venus Unveiled," AstroNews, December 1980.

Also see the lead feature in this issue.

A Last Chance for Halley

What may be the United States' last chance for a significant mission to Halley's Comet has been proposed in a report of NASA's Comet Science Working Group (CSWG) issued last November (see "United States May Miss Halley's Comet," AstroNews, January 1981). The report (NASA Technical Memorandum 82386) outlines a spacecraft mission, called the Halley Intercept Mission, which would fly by the nucleus of comet Halley to explore the comet's nucleus, coma, and tail.

In its report, the CSWG emphasizes that the return of Halley's Comet in 1986 provides "our only opportunity to carry out a direct investigation of a bright active comet which displays the full complement of cometary phenomena," until Halley's next return in 2061. Such a direct investigation is one of two essential goals the CSWG has identified for a comprehensive program for the initial exploration of comets. The other is a "rendezvous with the nucleus of a short-period comet."

The proposed Halley Intercept Spacecraft would provide numerous images, including color, of the comet nucleus with a resolution better than 100 meters. In addition, several scientific instruments would be included in the payload to determine the elemental and isotopic composition of the cometary dust and ice

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particles. The imaging system would also be used to observe and investigate the atmospheric and tail phenomena prior to closest encounter with the nucleus.

The spacecraft would be protected from impinging dust particles in the environment of Halley by a multi-layered shield. Solar panels would provide power to all spacecraft components during cruise, and batteries would be used during the encounter when the solar panels are folded back behind the shield for protection.

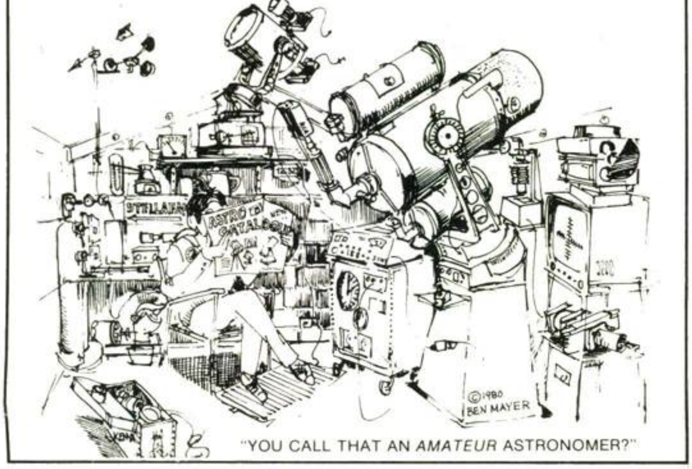
Because Halley's Comet is in a retrograde orbit, traveling around the Sun in a direction opposite to that of all the planets, the spacecraft and the comet would approach each other at a relative speed of nearly 60 kilometers per second — over 130,000 miles per hour. The spacecraft would be expected to enter the outer fringes of the comet dust environment about three hours before closest approach. The trajectory would be targeted to approach within 2000 km (1250 miles) of the comet's nucleus on its Sun-facing side. Within a few hours, the spacecraft would have passed the nucleus and exited through the other side of the dust envelope.

In total, over 8000 images of the comet would be taken during the mission, providing us for the first time with pictures of a comet nucleus and valuable information about the composition and dynamic processes of comets.

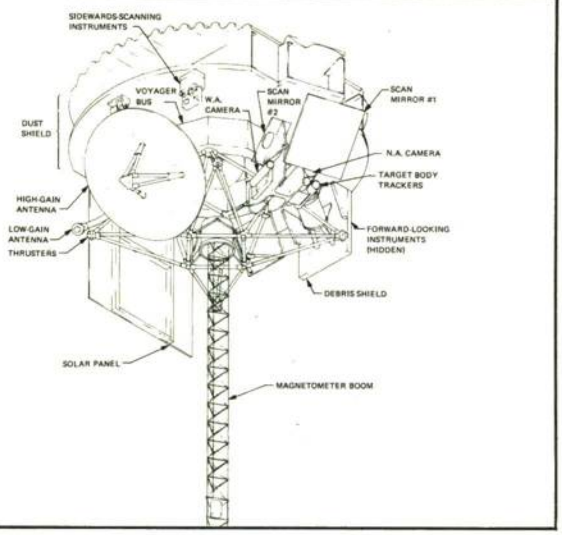
A number of other nations are currently planning missions to Halley's Comet, including a joint Soviet Union-France expedition and the Giotto mission of the European Space Agency (ESA). While some have proposed that the U.S. cooperate in the ESA mission, Joseph Veverka, of Cornell University and the chairman of the CSWG, argued that this would be inadequate. "There has been an attempt to beguile people into believing that an insignificant role in the European Giotto mission would be an adequate U.S. participation in the worldwide effort to study Halley. For several important technical reasons," Veverka continued, "this assertion is simply not true."

In its report, the CSWG claims that the proposed Halley Intercept Mission "is the only one which is sufficiently sophisticated to address adequately the unique Halley opportunity and the objectives of the United States science community." While emphasizing the value of coordinating all efforts to study Halley's Comet and strongly endorsing the International Halley Watch Program, the CSWG concludes that the Halley Intercept Mission "represents the single indispensable element of this worldwide effort."

"Should we miss this unique opportunity," the NASA report concludes, "it will be left to our descendants in the next century to fulfill one of the two essential elements in NASA's Comet Exploration Program."



"YOU CALL THAT AN *AMATEUR* ASTRONOMER?"



Instrumentation of the proposed Halley Intercept Mission Spacecraft is shown in this NASA diagram. The dust shield will protect the spacecraft on its journey through the comet's coma, and the solar panel will be folded down for protection while batteries supply power during the flyby.

Another "Largest Telescope"?

Last month AstroNews reported that the University of Texas had endorsed McDonald Observatory's plans to build a 300-inch telescope ("McDonald Plans 300-inch Telescope," AstroNews, February 1981). But McDonald's proposed instrument may not be the world's largest for long, if at all, because the University of California's plan to build an even larger telescope (see "A 400" Telescope?" in AstroNews, ASTRONOMY, August 1979) has received a substantial boost in the form of a $1.1 million allocation to Lick Observatory from the University of California (UC) Board of Regents. Preliminary estimates put the total cost of design, development, and construction in the tens of millions of dollars.

The $1.1 million allocation will be spent over the next two years on experimentation and design. It represents a serious commitment to the project by the University, according to astronomer Robert Kraft, acting director of Lick Observatory at UC Santa Cruz and administrator of the telescope project.

The proposed ten-meter (400-inch) telescope will be four times more powerful than the 200-inch reflector on Mt. Palomar, and nearly three times more powerful than the world's current largest telescope, the six-meter (236-inch) in the USSR.

The new telescope will enable astronomers to extend their observations of distant galaxies by several billion light-years, allowing them to look that much further back toward the beginning of time. Such observations should reveal galaxies actually in the process of formation and will be crucial in determining the size and age of the universe.

"It has been said," Dr. Kraft notes, "that the two great questions scientists can address are the origins of the universe and the origin of life. Studies with the ten-meter telescope will certainly contribute to the first of these and possibly to the second."

Design of the ten-meter telescope will require solutions to a number of serious technical problems and the application of new technology, he added. A team of astronomers, physicists, and engineers drawn from several UC campuses has been working on the design. Specialists from industry and the national astronomical community have also contributed to the project.

"To be feasible," Kraft says, "the telescope will have to be shorter, lighter, and less expensive than a simple scaling-up of current telescopes would allow." The telescope design team has proposed using a mosaic of thin, hexagonal segments for the *primary mirror.* A supporting structure and computer-operated control system will keep the segments oriented so that they function as one mirror. In contrast, the smaller McDonald instrument will have a single, though extraordinarily thin, primary mirror.

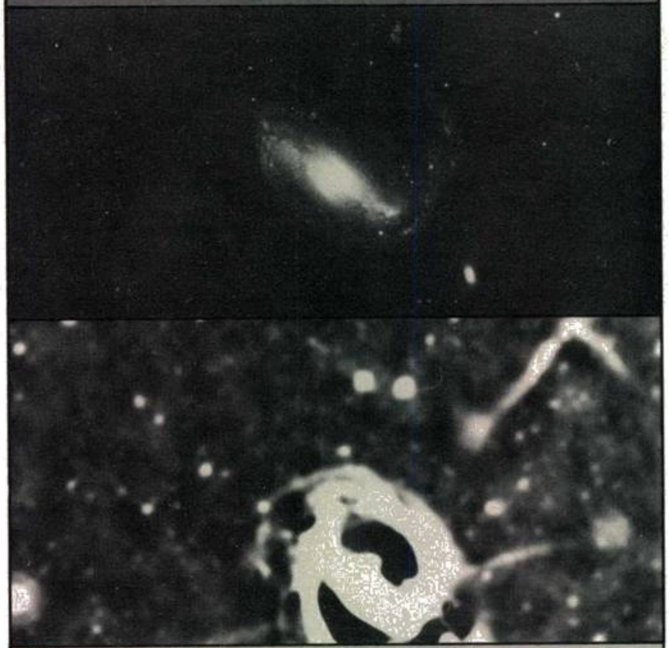
The new $1.1 million from the regents will fund the building and testing of a large-scale prototype of a section of the primary mirror control system. The money also will be used to test a method of making the individual mirror segments.

"No one has ever made a large-scale segmented telescope mirror before," says Kraft. "Because of its unique construction features," he says, "we expect that the ten-meter telescope should be no more expensive than a conventional five-meter telescope of comparable versatility."

To make the construction of the telescope possible, a substantial donation from a private source is being sought. "We are looking for the James Lick of the 1980s," Kraft says. Lick, a wealthy San Franciscan, financed the University of California's establishment of Lick Observatory a century ago.

A full report, presenting the overall design concept for the telescope and outlining a construction schedule, will be completed this year.

Mysterious "Spikes" in Galaxy



Computer-enhanced pictures of astronomical bodies often expose phenomena not visible in ordinary photographs. A recent example involves a mysterious source of radiation emanating from NGC-1097, a barred spiral galaxy. A set of black and white photographs, taken by an optical telescope at Cerro Tololo Observatory in Chile, was the only source of research material available to scientists studying the phenomenon. The Imaging Processing Laboratory at the Jet Propulsion Laboratory (JPL) in Pasadena, California, took the photos (one of which is shown at top) and enhanced them with an IBM System/370 Model 158 computer. The results revealed strange radiation "spikes" jutting through the galaxy (lower photo above). Scientists have yet to explain these mysterious "spikes." Photos courtesy of IBM and JPL.

Supernova in Strange Galaxy

Astronomers in Chile have reported the discovery of a supernova in a relatively nearby galaxy which appears to have undergone a collision with another galaxy. The galaxy, Fornax A, is located about 50 million light-years away. Dr. Francois Schweizer of the Cerro Tololo Inter-American Observatory near La Serena, Chile, said that Fornax A is "exceedingly unusual" because it appears to be a mixture of stars formed by the relatively recent collision of two ordinary galaxies. Such collisions are thought to produce bursts of star formation, followed some tens of millions of years later by an increased rate of supernova explosions.

The new supernova was discovered on November 30 of last year by Dr. Marina Wischnjewsky and Dr. Jose Maza of the University of Chile while they were conducting a survey of a number of galaxies on a special wide-field telescope at Cerro Robles in Chile. On December 10, 1980, Dr. Anthony F.J. Moffat of the University of Montreal used Cerro Tololo's 158-inch (4 meter) reflector to confirm the phenomenon as a genuine supernova.

A supernova occurs when the interior of a star collapses, triggering a giant thermonuclear explosion. The light from the explosion is as great or sometimes even greater than the combined light emitted by the billions of stars in the "parent" galaxy. The last supernova to be discovered in our own Galaxy was observed by the German astronomer Johannes Kepler in 1604.

Supernovae play a key role in the evolution of the universe as the last step in a cycle which changes hydrogen and helium into carbon, nitrogen, oxygen, and other heavier elements which may then be incorporated into newly forming stars and planets. The formation of our own solar system, astronomers now think, may have been triggered by the shock wave expanding out from a nearby supernova into the interstellar medium of gas and dust, causing parts of it to collapse into protostar clouds.

Meteors on Exhibit

The American Museum of Natural History in New York City will open a new exhibition on April 30 — the Arthur Ross Hall of Meteorites. The exhibit will explore the development of meteorites and the clues they provide for studying terrestrial and planetary history.

This permanent exhibition will feature a wide variety of meteorites, rock samples from the Moon, an audio-visual program describing the impact of meteorites, and a series of exhibits examining the origin and significance of meteorites.

"We are trying to increase the public's awareness of the important and exciting new scientific knowledge and recent advances in the study of meteorites and related planetary sciences," said Dr. Martin Prinz, chairman of the Museum's Department of Mineral Sciences and scientific consultant to the new hall. "We want to show what meteorites have told us," he added. "We will show what happens in flight, what happens when they land, and what they can tell us about our own planet."

The new hall, which represents almost two years of planning and construction, has been supported by Arthur Ross, a Museum Trustee and a generous contributor to museum activities for many years.

The centerpiece of the Arthur Ross Hall of meteorites is the 31-ton "Ahnighito," the largest meteorite found on the Earth's surface. It will be flanked by companion meteorites, "The Woman" (three tons) and "The Dog" (one ton).

The hall also will feature Moon rocks on loan from NASA, which represent the three main rock types found on the lunar surface.

A 10-minute audio-visual program will present film footage from a 1928 Russian expedition in Siberia to investigate the mysterious "Tunguska event," in which thousands of square miles of forests were destroyed. Scientists now speculate that the area was struck by a comet. The program also includes a NASA film describing simulated meteorite impacts.

Another section of the hall will include maps showing where meteorites fell and were found in this country and throughout the world. Other exhibits explain how meteorites are formed and what secrets they contain about the solar system, and samples of the five main types of meteorites that may have played an important role in the origin and development of planets will be displayed in the new hall.

"Meteorites can tell us about the beginning of the solar system," Dr. Prinz explained. "They can tell us about the relationship between the planets and they can put the history of Earth in perspective."

AstroNews

Space Science Symposium

On March 23-24, the National Air and Space Museum of the Smithsonian Institution in Washington, DC, will sponsor a free symposium titled, "Space Science Comes of Age: Perspectives in the History of the Space Sciences." The program will include lectures and panel discussions featuring a number of prominent space scientists, such as Leo Goldberg of the Kitt Peak National Observatory, James A. Van Allen of the Smithsonian Institution, and Robert Jastrow of the Goddard Institute for Space Studies.

Two sessions on the first day focus on recent advances in astronomy made possible by space science, such as high energy astronomy, the geology of the Moon, and ultraviolet stellar spectroscopy. The second day features a discussion of the history of recent space research. All three sessions will include a panel discussion by the participants as well as individual presentations.

The symposium, which will be held at the National Air and Space Museum in Washington, will be free and open to the public.

Nationwide Radio Telescope

Astronomers at Caltech and the Jet Propulsion Laboratory (JPL) have completed a feasibility study of a nationwide array of large radio dishes that would, in effect, transform the entire country into an immense radio telescope. This transcontinental radio telescope, they have concluded, would be both economical and a powerful scientific tool, with thousands of times more resolving power than the largest optical telescopes.

The system, which would be operated as a national facility, would also be far superior for the technique known as Very Long Baseline Interferometry (VLBI) than the current *ad hoc* combination of radio telescopes now used in such studies. This technique involves operating two or more widely separated radio telescopes simultaneously, and combining their data to give the effect of one extremely large telescope. During an array's operation, the Earth's rotation produces a scanning effect that allows the VLBI array to "build up" a radio map of a celestial object. (See "Using Earth as a Radio Telescope," ASTRONOMY, October 1979.)

The transcontinental radio telescope would produce the first high-quality radio maps of the structures of such exotic objects as quasars, forming and dying stars, and other objects in our Galaxy and beyond. The system could also be used to make more precise measurements of astronomical distances and to study with much greater accuracy the Earth's rotation and tectonic plate movements.

An array of ten matched radio dishes, each about 25 meters in diameter, could be constructed throughout the continental U.S. and in Alaska and Hawaii for about $38.8 million, say the researchers, led by Caltech Professor of Radio Astronomy Marshall H. Cohen. Operation costs would run $4.8 million per year, and the array would be controlled by a single computer at a central operations center.

The purpose of the Caltech-funded study, say the scientists, was to evaluate the idea of a transcontinental radio telescope array, first proposed in 1977, in light of recent substantial advances in VLBI. Since the 1960s VLBI has been used to give astronomers an unprecedented look at the structure of astronomical objects. Astronomers were able to produce the first crude radio maps of distant galaxies with violent and active centers. The maps revealed such phenomena as massive jets of matter and energy spewing from the galactic cores.

Using VLBI, they were also able to make precise studies of the Earth, by using distant quasars as fixed beacons to determine the relative movement of the radio telescopes. In this way, precise measurements of the Earth's rotation and of the movement of such crustal features as the San Andreas fault were made.

"VLBI is unmatched in angular resolution by any other astronomical technique," said the Caltech-JPL study. "In extragalactic astronomy it is the only tool available for determining the structure of the energy source in quasars and active galaxies."

"In galactic astronomy," said the study, "a VLBI array can be used for studying a variety of objects, including the powerful celestial masers associated with the birth and death of stars, and has potential for measuring the distance to these objects throughout our Galaxy and in neighboring galaxies."

Because the individual radio dishes of the array would be so widely separated, it is possible to make such astronomical measurements trigonometrically, said the report, greatly reducing current uncertainty about fundamentally important measurements like the distances to stars, galaxies, and other objects.

In addition, the VLBI array could test the theory of relativity by comparing theoretically predicted and actual measurements of the gravitational deflection of radio waves from stars by the Sun.

Radio telescopes throughout the world have already been joined in VLBI studies, and in this country a group of seven existing dishes (in Massachusetts, West Virginia, Iowa, Texas, and California) have been involved in VLBI studies since 1975. Although such arrangements have provided a powerful tool for mapping radio-emitting objects, the network has several major drawbacks.

"Among the inadequacies of the current system are its poor geographic coverage, the poor short-wavelength performance of the antennas, and the lack of standard equipment and central coordination," said Dr. Cohen. "These problems mean that the full potential of VLBI cannot possibly be realized with the existing system."

Dr. Cohen pointed out that the transcontinental array of matched telescopes, capable of operating at wavelengths as short as 1.3 centimeters, could produce huge scientific dividends. "The time is ripe for a mature instrument which will exploit the potential of VLBI with high dynamic range, high resolution maps of a wide variety of astronomical objects."

Astronomy Bulletin Board

A unique service to amateur astronomers with home computers has been started in New York. By dialing (212) 787-5520, anyone with the proper equipment can gain access to the "Amateur Astronomer's Bulletin Board," provided free 24 hours a day by Pierre Schwob, president of the newly-formed Program of the Month Corporation.

Messages can be entered on a disk for access by others, or the user may scan a summary of all messages, which includes date of entry, the name of the sender, the name of the person to whom the message is directed, and a one-line description of the subject of the message. The user can also use the phone line to retrieve messages, or kill one of his own messages.

A "user's file" may be retrieved, which contains the name and address of all past and current users of the system. Access to the operating system (CP/M) can be gained by a user with a password, available by calling between 1 and 5 p.m. Eastern Time (standard or daylight).

One of the services provided is the "Astro-Bulletin," a print-out of astronomical data and coordinates valid for the current month. Such information as the phases of the Moon, coordinates of the planets and comets, and Algol eclipse times are included.

Anyone with a terminal and a modem or an acoustic coupler can dial into the system. Both 300 and 110 bauds are supported (8 bits — no parity standard). The system has been on line since the end of last September, and Schwob reports that it *already has over 70 regular* users, of which more than half seem to be amateur astronomers.

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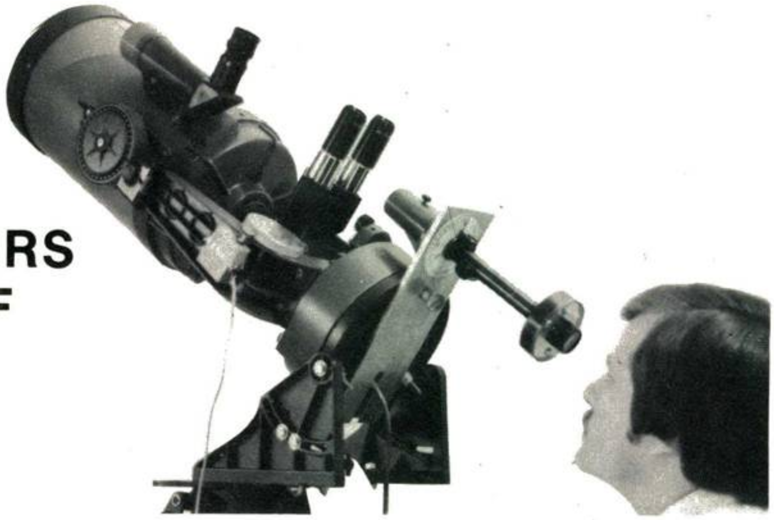

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Solar Magnetism: A NEW LOOK

BY LEON GOLUB

Astronomers used to think of magnetic fields as rare and relatively unimportant in the grand scheme of things. Certainly the Earth has a magnetic field, and early in this century George Ellery Hale showed that sunspots have tremendously strong magnetic fields, but these discoveries remained isolated. Magnetic fields did not fit into a larger picture, and their influence seemed small when compared with other forces of nature. There also existed a more subtle effect, stemming from a general feeling that on a cosmic scale matters progress in a calm, stately fashion. Magnetic fields imply electric currents, motion, and a type of dynamic activity which seemed out of place among the stars and galaxies. It now appears that activity and rapid change are very common features in the universe. From small objects to huge cosmic systems, from tiny "magnets" of atoms to the Crab supernova remnant, and perhaps even to the scale of clusters of galaxies, magnetic fields often play a major role in theoretical explanations of observed dynamical processes. Of course, many discoveries over the past fifty years have contributed to producing a sharp change in our views of the prevalence of magnetic fields: there are magnetospheric substorms on Jupiter and on Earth, flares and prominence eruptions on the Sun, relativistic electrons and synchrotron emission from the Crab Nebula, and radio pulses from rapidly rotating neutron stars. Astronomers now seem to be finding magnetic fields everywhere!

With the growing evidence for the ubiquity of magnetic fields, researchers feel a growing need for an adequate theory to account for the generation of such fields in nature. This does not require any advance in the basic physics, which the great physicist James Clerk Maxwell clarified a century ago with his unified theory of electricity and magnetism, but a better understanding of the variety of ways astronomical objects can generate electrical currents, since it is ultimately such currents that produce magnetic fields.

The origin of these so-called *dynamo theories* lay in the attempt to explain the existence of Earth's magnetic field. Seismological evidence pointed to the existence of a fluid core in the Earth, a metal core and therefore a good electromagnetic conductor. Scientists found that suitable motions of such a fluid conductor could produce a magnetic field like the one observed. Soon after completion of this early work, attention focused on the Sun as a promising candidate for further theoretical modeling.

A major stumbling block in all of these calculations is our basic lack of knowledge about the fluid flows either in Earth's core or inside the Sun. The calculations involved in dynamo models are extremely complex, and are, unfortunately, such that it is rarely possible to "guess" at the answer which will come out of a particular calculation. Although there are now some general rules for dynamo calculations, in practice it's still necessary to work through a long computer simulation for any given fluid flow pattern to find out whether that particular flow will produce the type of magnetic field pattern actually observed. Under these conditions, any advance in our knowledge of the flow patterns in the Earth or the Sun represents significant progress. The problem is, of course, no easier for other astrophysical objects, since we know even less about them, but any appearance of simplicity in modeling some of the more exotic objects comes only from our lack of detailed observations with which to compare a calculated model.

The Solar Activity Cycle

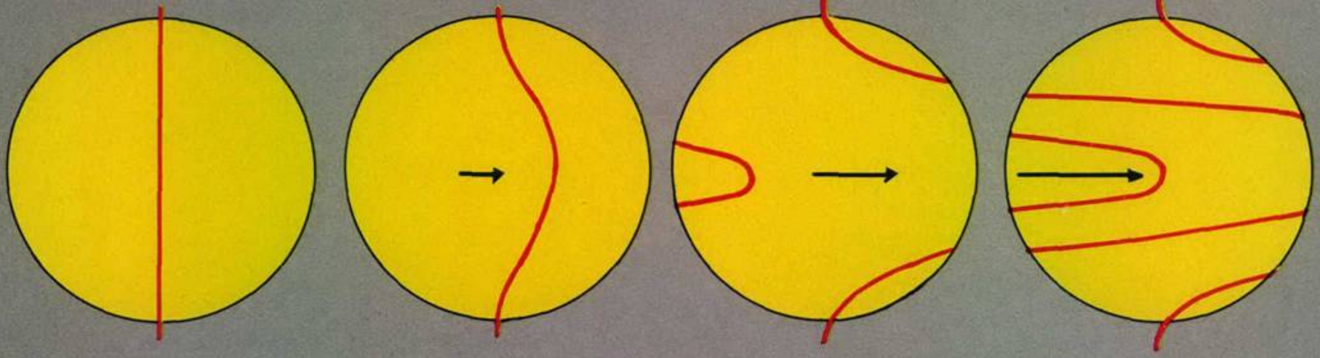
The case of the Sun presents a formidable but instructive challenge for dynamo theorists, because we can observe the eruption of magnetic flux from the solar interior in great detail. (The term *flux* is a measure of the strength of the magnetic force. In a sense, it is a measure of the number of lines of force crossing a unit area.) The fundamental property that we must explain — aside from the existence of a magnetic field at all — is the solar cycle. This phrase has a number of meanings, and as we'll see below, recent observations may fundamentally alter the meaning of the word "cycle." But the traditional picture of the solar cycle has three primary components:

- The activity cycle. Activity on the Sun stems from the "bubbling up" of magnetic fields to the surface. These fields emerge in relatively small areas known as "active regions" which contain especially strong concentrations of magnetic flux in the form of sunspots. Scientists have long known that the number of sunspots and spot groups, along with related activity such as flares and prominence eruptions, varies over a cycle lasting on the average about eleven years. This past year, for instance, was a so-called "maximum year," the peak of the current cycle. 1976 was a "minimum year," and presumably the next minimum will occur some time around 1987.
- The latitude migration of sunspots. A curious property of sunspot occurrence, noticed over a century ago, is the tendency for spots to occur only within restricted belts of activity. These belts tend to be symmetric above and below the solar equator, and they "migrate" during the course of the cycle. Solar activity first breaks out at high latitudes (around 40° north and south) and then moves systematically toward the equator until it virtually blends into a single wide equatorial band.
- Hale's law and the reversal of polarity. Soon after Hale discovered that sunspots had strong magnetic fields, he found that they followed a fairly strict rule in their orientation. Sunspots represent only a slice through a vertical magnetic field structure emerging from inside the Sun. A region of activity containing spots is in reality a three-dimensional structure rather like the field of a bar magnet lying horizontally just below the solar surface. Where the strong field breaks through the surface we see a spot — or spots, since they tend to come in pairs. What Hale found was that the "bar magnets" follow fairly strict laws of orientation: they have a strong tendency to be oriented east-west, and all spot pairs in either the northern or the southern hemisphere tend to have the same leading polarity — that is, if the leading (easternmost) spot of a pair north of the equator has an "outward" polarity (with lines of force emerging out from the solar surface), the trailing (westernmost) spot will be "inward" in polarity. Moreover, spots in the other hemisphere have an opposite orientation, so the polarity rule reverses across the equator.

The polarity of spots follows this rule throughout the entire 11-year cycle. But when a new cycle begins, all the orientations are reversed. It seems like the entire process repeats, but in a "mirror" which reverses the direction of the magnetic fields. (In order to include this reversal of polarity, many researchers prefer to speak of a 22-year solar cycle instead of 11 years, which they regard as only half of a full cycle.)

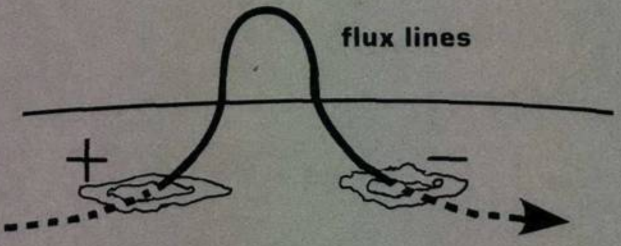
This picture of the solar cycle focuses mainly on the behavior of sunspots and groups of sunspots. (See "Sunspots," ASTRONOMY, May 1980.) Of course, these have associated with them the other phenomena which we call solar activity: flares, radio noise storms, mass ejections, and other violent processes. During a single 11-year solar cycle, the frequency of such events increases to a maximum over three to five years and then slowly decreases during another five to eight years. The entire process then starts over again for a new cycle.

The solar activity cycles are not exactly regular, usually

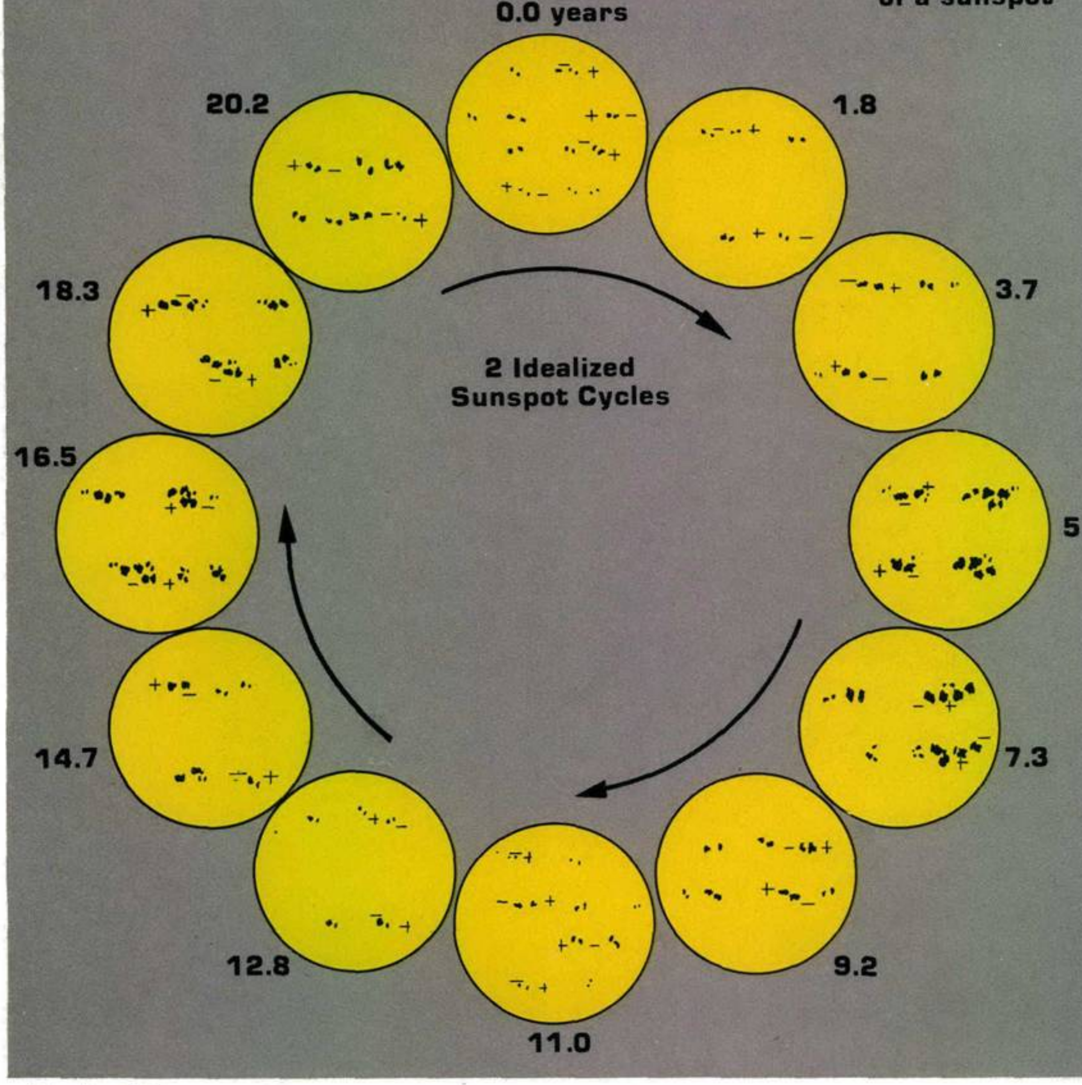


The Sun's faster rotation at the equator soon wraps up a poloidal magnetic field.

Fields, Spots, and Cycles

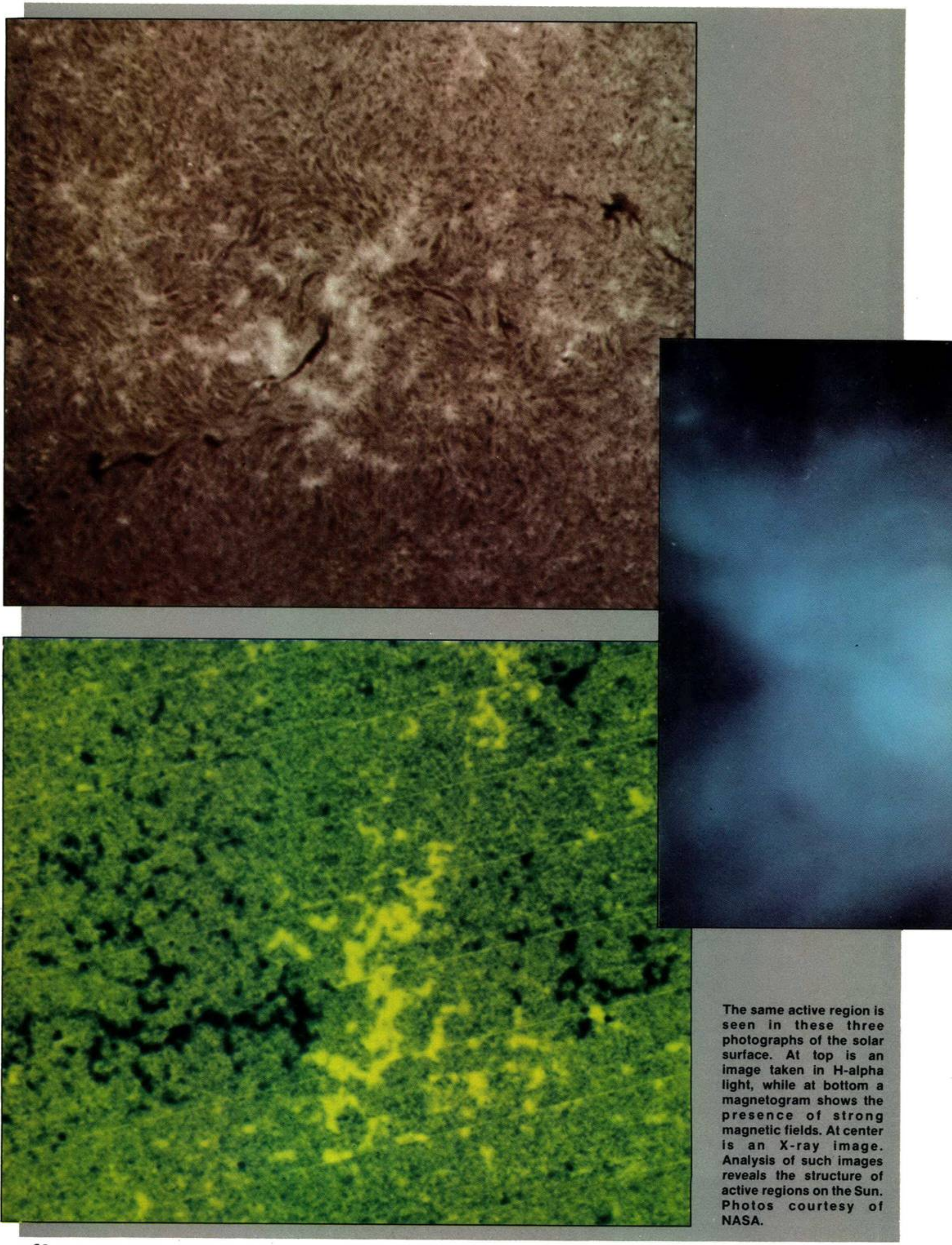


the magnetic field structure
of a sunspot


0.0 years
1.8
3.7
5.5
7.3
9.2
11.0
12.8
14.7
16.5
18.3
20.2

2 Idealized Sunspot Cycles

As each 11-year sunspot "season" progresses, spots become larger, more numerous, and occur at lower solar latitudes. As they fade out, the next cycle's spots appear at high latitudes. The magnetic polarities of sunspots also change, but a full cycle takes two "seasons."



The same active region is seen in these three photographs of the solar surface. At top is an image taken in H-alpha light, while at bottom a magnetogram shows the presence of strong magnetic fields. At center is an X-ray image. Analysis of such images reveals the structure of active regions on the Sun. Photos courtesy of NASA.

running several years shorter or longer than the average of 11 years between successive maxima. The *amplitude*, or peak level of activity reached at maximum, is also not predictable and can vary considerably from one cycle to the next. In the extreme, it seems the cycle can even disappear entirely for several decades at a time, as Jack Eddy has recently shown through a search of historical records. (See "The Case of the Missing Sunspots," ASTRONOMY, February 1981.)

The Generation of Magnetic Fields

If we set aside these complications and concentrate on the average properties of the activity cycle, it is clear that theorists have been fairly successful in producing a set of dynamo models which can both reproduce the cycles and also explain Hale's polarity law. The standard theory still in use today originated back in 1955. This group of models represents the simplest set capable of reproducing the observed properties of solar activity we've described — so far.

The key to magnetic field generation is the generation of electric currents which in turn produce magnetic fields. An electric current — by definition a flow of charged particles — exists only where the particles themselves are in motion. However, the magnetic field produced by the current can propagate to great distances, or even fill all of space. Thus the fluid motions inside the Sun can generate electric currents whose associated magnetic fields reach not only the solar surface but out to the Earth's orbit and beyond.

Since we can't actually see inside the Sun, we must rely on theory or on observational clues from surface phenomena in order to deduce what the internal motions are. In particular, we need to focus on those aspects of the internal fluid motions which can generate magnetic fields and cycles of activity like those actually observed.

Theoretically — at least in the simplest of the dynamo models — there are two major elements of the flow pattern inside the Sun. The first is *differential rotation*, a term which refers to the fact that the Sun does not rotate as a rigid body. Even at the visible surface, the equator rotates more rapidly than the higher latitudes, so that sunspots near the equator complete a rotation several days sooner than those at higher latitudes. (We see such differences in rotation rate as a function of latitude even more clearly on Jupiter, which rotates every 10 hours instead of once a month like the Sun.)

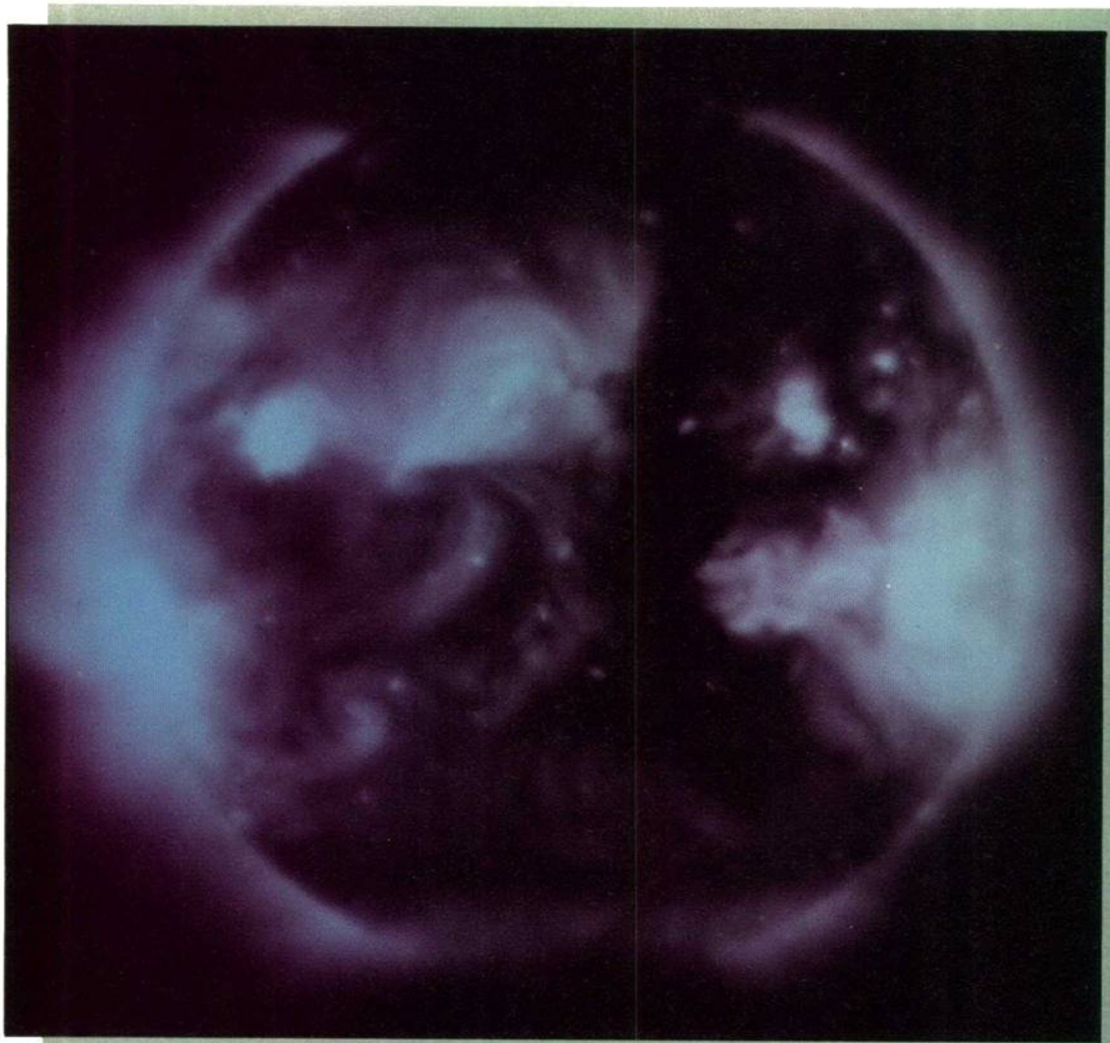
More important for modern dynamo theory than the *visible* differential rotation of the solar surface is another type which, we now believe, is present in the Sun. Recent studies, including sophisticated analyses of rising convective bubbles and patterns of turbulence on the solar surface, show that the interior of the Sun actually rotates more rapidly than does the surface. We don't know how far down into the Sun this increase persists, but there is good reason to believe that the rotation rate continues to increase down to considerable depths. This type of differential rotation is a very efficient mechanism for amplifying the strength of magnetic fields in the Sun and it's probably the key mechanism for producing the fields which bubble up from the interior. (From here on, "differential rotation" will refer only to this internal increase in the Sun's rate of rotation, not to the surface variation with latitude.)

Differential rotation produces a magnetic field which stretches around the Sun along parallels of latitude. To see how this happens, imagine a north-south oriented magnetic field line penetrating the Sun, but not directly on its axis of rotation. The term for this type of field is *poloidal*, because it runs parallel to the north-south pole axis. Since the interior of the Sun rotates more rapidly than its surface, the interior portions of this magnetic field line are dragged around more often than those portions at or near the surface. After several rotations, the field becomes "wound up," and takes on a strong east-west orientation. Such a field is called *toroidal*, because it runs toroidally (in a doughnut shape) around the north-south axis.

Thus, differential rotation produces in a natural way the polarity law found by Hale. The strong magnetic fields are oriented in the proper manner and there is a mirror symmetry between the northern and southern hemispheres. It's also possible, through somewhat more subtle arguments, to show that this mechanism can also produce the observed migration of solar activity (such as sunspots) where activity erupts first at high latitudes and then migrates down toward the equator. At this point, however, it is more important to discuss the way in which a full cycle evolves, since so far we have only a mechanism operating in one direction and we still need to account for the observed reversals.

What we are looking for is a mechanism — a second type of fluid flow pattern — that can produce another toroidal field with a magnetic polarity opposite to that in the previous cycle. Recalling that the Sun's internal differential rotation is the basic mechanism for the amplification of magnetic fields, and that it operates on a poloidal field to produce a toroidal field, then what we need is some flow pattern which can take this toroidal field and produce from it a new poloidal field oriented in the opposite direction to the one which started the cycle. Then a new cycle can begin with all of the magnetic field directions reversed.

The key to this reversal process is the observation that the Sun has a convection zone. This is a region near the



This X-ray image of the Sun reveals the presence of a number of small magnetically active regions as well as several large-scale areas which can be identified with sunspots. It now appears that as the number of sunspot groups declines, the number of small active regions increases greatly. Photo courtesy of the Solar Physics Group.

surface which is bubbling and churning with a cellular type of flow pattern. *Convection* occurs in a fluid when the fluid must transport more heat than conduction is capable of carrying, so the fluid becomes unstable and begins to move the excess heat by a mass motion of the hot material itself. The most familiar examples of convection are boiling water and hot air rising from a radiator, but convection also occurs on a larger scale in the Earth's atmosphere and is a major influence on our weather patterns.

The rising convective cells in the Sun bring trapped magnetic fields up with them from the interior. This in itself will not bring about any polarity reversal, but the Sun's rotation now contributes in a crucial way. Because of the rotation, the rising fluid begins to twist slightly, counterclockwise in the North and clockwise in the South. The same Coriolis force responsible for the similar well-known effect in terrestrial weather patterns causes this. Note, however, that on Earth the motions are mostly horizontal surface effects, while in the solar case the motions are mainly radially outward from the deep interior.

The result of this so-called *helical convection* is to take some of the east-west toroidal field and turn it into a north-south oriented poloidal field. Most important, the new poloidal field has an opposite polarity from the field which started the cycle. Differential rotation then acts on the new field to produce a new cycle of activity with all the polarities reversed.

A New Look at Solar Activity

As is often the case in scientific research, improved methods of observation are rendering the above commonly accepted picture somewhat doubtful. The story has developed through a series of improvements in observational techniques beginning in the mid-sixties, which led to a dramatic increase in our ability to detect small centers of activity on the Sun. The development of a high spatial resolution magnetic field measuring instrument (in the present context, principally at the Kitt Peak National Observatory) and of imaging optics for the soft X-ray region of the spectrum (at the Harvard-Smithsonian Center for Astrophysics) has led to an enormous increase in sensitivity for detecting small, short-lived regions of emerging magnetic fields on the Sun.

The immediate result of the first high-sensitivity X-ray observations, which culminated in 1973 with the launch of Skylab, was the realization that previous studies (which focused only on sunspot regions) may have missed much of the action. The preferred method of magnetic flux eruption at the solar surface now appears to be in numerous small, rather than large, centers of activity. We found that most of the solar magnetic flux emerged in regions too small to have visible sunspots and lasted for only a day or less. The Sun is covered with hundreds of these small regions and as many as a thousand of them might emerge for every large sunspot region which is seen.

The emphasis on larger active regions in most of the earlier studies was quite natural, since for many years we couldn't see the smaller regions at all. It was especially the combination of improvements in magnetic field measurement and the development of X-ray imaging which together showed that enormous quantities of magnetic flux emerge from the solar interior *in the form of very small regions.*

This combination of techniques is necessary because for each alone there could be alternative explanations for the existence of these numerous small regions. In the magnetograms alone, for example, one often observes bits of magnetic flux torn away from a large active region by the turbulent fluid motions at the solar surface. There are at all times a large number of such pieces being pushed around on the Sun's surface, and often two bits of magnetic flux with opposite polarity happen to be near each other. On a magnetogram they will look the same as a complete loop of emerging magnetic field, even though they are in reality not connected to each other. However, we can make the X-ray images record only the emission from closed loop structures, so that we can separate the true emerging flux regions from the "impostors." Thus we now have a powerful new technique for studying the properties of small-scale emerging magnetic fields at a level of sensitivity which reveals an entirely new dimension of solar activity.

The early 1970s, when this work was completed, corresponded to the declining phase of that solar cycle. The level of activity (as measured by sunspot numbers) had reached a peak in 1969 and was slowly receding to the predicted minimum of activity in 1975-76. The Skylab missions ended early in 1974, but the X-ray program continued by means of rockets which once or twice a year put an X-ray telescope above the atmosphere for a few minutes at a time. These "snapshots" were meager in comparison with the wealth of Skylab data, but they were enough to reveal another totally unexpected aspect in the behavior of these small-scale regions of emerging flux.

The combination of X-ray and magnetogram data had established that more magnetic flux was emerging in small bits than in large active regions, at least during 1973 when the Skylab data were taken. With the solar cycle winding down during the mid-70s the obvious question was, what will happen to the small-scale fields? The great surprise was that as the number of large regions dwindled away, the number of small regions increased dramatically! By 1976, at solar minimum, the sunspot activity had, as expected, nearly disappeared. But a 1976 rocket flight showed that the number of small regions had nearly doubled. Another rocket flight several weeks later produced the same result, so that the odds of a chance fluctuation producing an anomalous measurement on the first flight became negligible. A re-examination of older, pre-Skylab rocket data showed that at the previous maximum of activity in 1969 and 1970 the number of small regions had been much lower than in 1973, whereas the number of sunspot regions was, of course, quite large.

Magnetic Fields

About 150 years ago, the English scientist Michael Faraday scattered some iron filings on a piece of paper covering a magnet. When he jostled the paper a little, the iron filings arranged themselves into a regular pattern of curving lines. Seeking to understand how magnetism worked, Faraday theorized that the space around a magnet was somehow filled with a "force field," outlined by curving "lines of force" along which the strength of the magnetic force was constant. Thus was born the concept of magnetic fields.

Faraday's idea of a force field defined by lines of magnetic force was later given mathematical expression by James Clerk Maxwell. Maxwell, one of the greatest physicists of all time, succeeded in uniting all the phenomena of electricity and magnetism into one elegant theory. In just four simple equations, he was able to express the essential unity of electricity and magnetism, and show how they were inseparably related. Any motion of electric charge will, according to the theory of electromagnetism, generate in the space around it a magnetic field, and, likewise, the motion of a magnetic field will produce an electric current. Electricity and magnetism, according to Maxwell's equations, are simply two aspects of one basic force in nature: the electromagnetic force.

The best estimates of the total amount of magnetic flux emerging in large and small regions combined showed that the amount at all times during the cycle is, on the average, unchanging. What changes instead is the relative proportion of large to small regions. Solar maximum is the time when a larger fraction of the flux emerges in the form of sunspot regions. At solar minimum the flux instead comes up in a large number of very small regions spread all over the Sun.

These new observations give a new meaning to the term "solar cycle." Rather than being an oscillation in the *amplitude* of magnetic flux emergence, the cycle now appears to be an oscillation in the *size distribution* of the activity. It is tempting to add now a fourth property of the solar cycle to those listed earlier:

- The rate of generation of magnetic flux does *not* change during a solar cycle — instead, the observed cycle represents a shift from large emerging regions to numerous small regions, and then back again.

This rule is actually stronger than any other deduced from the evidence to date. However, it is clear not only that substantial amounts of small-scale magnetic flux emerge from the solar interior, but also that these small-scale fields have a very different behavior throughout the cycle than we would previously have expected. Whether or not there is a true constancy to the rate of magnetic flux generation, it is certainly true that we can describe the behavior of the solar dynamo more accurately by an oscillation in scale sizes than by a simple variation in the total magnitude of the flux produced.

The implications of these new observations could be substantial. If the large sunspot regions represent only a part of the total magnetic picture, then the theoretical efforts at modeling their behavior may have missed much of the action. None of the existing dynamo models explain the production of such copious quantities of small bundles of flux in the Sun, and many of them can't deal with these small-scale fields at all. Certainly no models exist which reproduce the dramatic alternation between the production of a few large and then many small regions. There is clearly a need for a major re-examination of the theories of magnetic field generation, and in particular of those theories which attempt to describe cyclical patterns of activity.

The progress of science has generally followed a path in which new observations pointed out flaws in existing theories, thereby showing the need for a revision in our customary views. At the same time, new facts in themselves are meaningless without being integrated into a formal theory which we can tie into the larger body of existing knowledge. In this way, paradoxes and puzzles have generally led to major advances in our understanding.

The study of magnetic field generation in nature is currently gaining in importance as we realize more and more the major role played by magnetism in the cosmic order. With this increasing attention, it seems safe to predict that our understanding of exotic objects such as neutron stars, supernova remnants, and star formation regions will continue to increase. After all, we are now finally beginning to understand the production and activity of magnetic fields in the nearest and, to us at least, most important star — our own Sun.

Leon Golub is an astrophysicist at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts. He received his Ph.D. from MIT and has worked on solar X-ray studies from Skylab. Currently, he's involved in analyzing stellar X-rays with the Einstein Observatory, an orbiting X-ray satellite.

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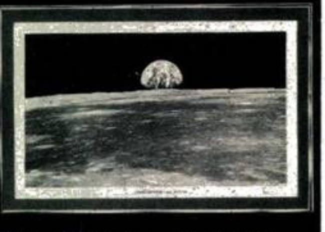

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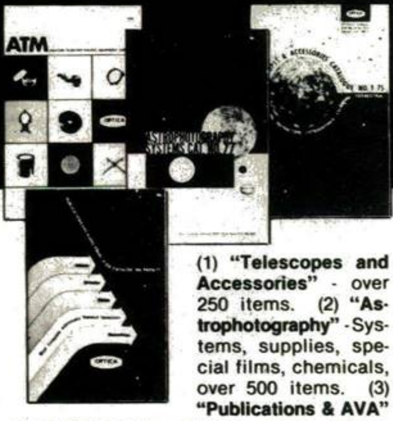

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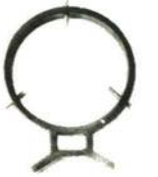

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WANTED — SF plastic models — *Space 1999* Eagle 1, and/or Hawk. State price & condition. Contact Chris Delawder, 916 Lois St., Ft. Walton Beach, FL 32548.

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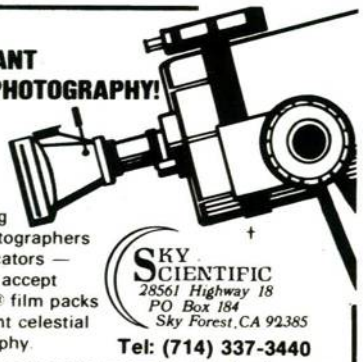

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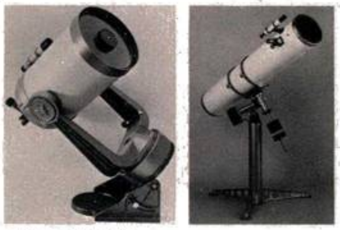

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close-up on gemini

through the eyepiece

The same month that marks the arrival of spring in the northern hemisphere also marks the oppositions of Jupiter and Saturn — and they're superbly placed for observation, so don't miss them!

Mercury

Tugged along by the Sun, Mercury moves eastward from Capricornus into Aquarius during March. Despite being at greatest western elongation on the 16th — an ample 28° — the little planet will be very hard to see because of its southerly declination.

If conditions are favorable, you may just catch sight of it early in the month (between the 5th and 10th) if you look about 4° above the east-southeastern horizon 45 minutes before sunrise. Mercury will be a magnitude +0.7 reddish dot of light, and medium powers on a telescope will reveal its 8 arc-second disk, between a third to a half lit.

Venus

Moving 8° nearer the Sun (its 10° elongation on March 1st becomes 2° on the 31st), Venus lies too close to the Sun for visibility this month. (Superior conjunction comes on April 7.)

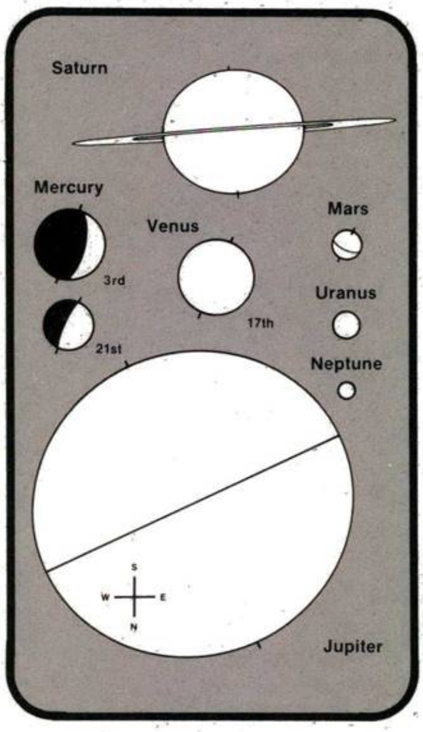
Moon

Lunar conjunctions have thinned out somewhat this month: there are only five of note. On the morning of March 4th, look for a 27½-day-old Moon (5% lit) about 3° below and to the right of Mercury just before sunrise.

At 4:00 UT on the 12th, a 5.8-day-old Moon will pass about a degree to the north of Aldebaran. (If you were watching from the Arctic, you'd see an occultation.) At the time of closest approach, the Moon and star will be low (14° elevation) in the west for observers on the east coast and high (60°) in the southeast for those on the west coast.

Leonard Pincus' photo of a meteor streaking through the Lagoon Nebula (M-8) wins the "Best Astro-Photo" award for March. The photo was a 2-minute exposure with a 50-mm lens at f/2. The camera rode piggyback on a telescope and the film, Ektachrome 400, was hypersensitized in forming gas.

On the 21st, the Moon, just past full, will overtake both Jupiter (at 1:27 UT; the Moon lying 2° 50′ to the north) and Saturn (at 3:47 UT; the Moon's distance being 1° 44′, again north). You'll see a pretty sight as the three objects rise together in the evening.



At 13:42 UT on the 25th, the Moon passes 4° 40′ north of Uranus. Only observers in the west will see the two at the moment of conjunction, because in other locations the sky will be brightened too much by oncoming sunrise.

Just before Last Quarter — at 17:34 UT on the 27th — the Moon overtakes Neptune, sliding by 2° 13′ north of the planet. But since conjunction comes after sunrise for all of North America, you'll have to observe the pair late in the predawn sky.

Earth

The vernal equinox arrives on March 20th (at 17:03 UT), when the center of the Sun's disk moves across the celestial equator into the northern hemisphere.

Mars

Moving toward conjunction on April 2nd, Mars lies too close to the Sun to be seen this month.

Asteroids

1 Ceres (at magnitude 7.7) lies in northern Gemini, close to Castor. On the 20th, it lies at the same declination and 23 minutes of right ascension to the west of Castor. Look for it at the following positions:

10th: 7h 5m 34s, +32° 13.3′
20th: 7h 10m 26s, +31° 56.5′

Ceres transits around 8 p.m. local time on March 15th.

2 Pallas (9.0) lies in western Eridanus; its positions:

10th: 3h 13m 43s, -11° 47.2′
20th: 3h 30m 14s, -9° 58.8′

Pallas sets around 8 p.m. local time at mid-month.

3 Juno (10.2) is near junction of the constellations Virgo and Libra; its positions:

10th: 14h 31m 43s, -5° 42.6′
20th: 14h 28m 28s, -3° 51.3′

Juno rises around 11 p.m. local time on March 15th.

4 Vesta (6.7) lies just to the east of Leo's sickle; its positions:

10th: 10h 19m 31s, +20° 46.9′
20th: 10h 11m 43s, +21° 28.6′

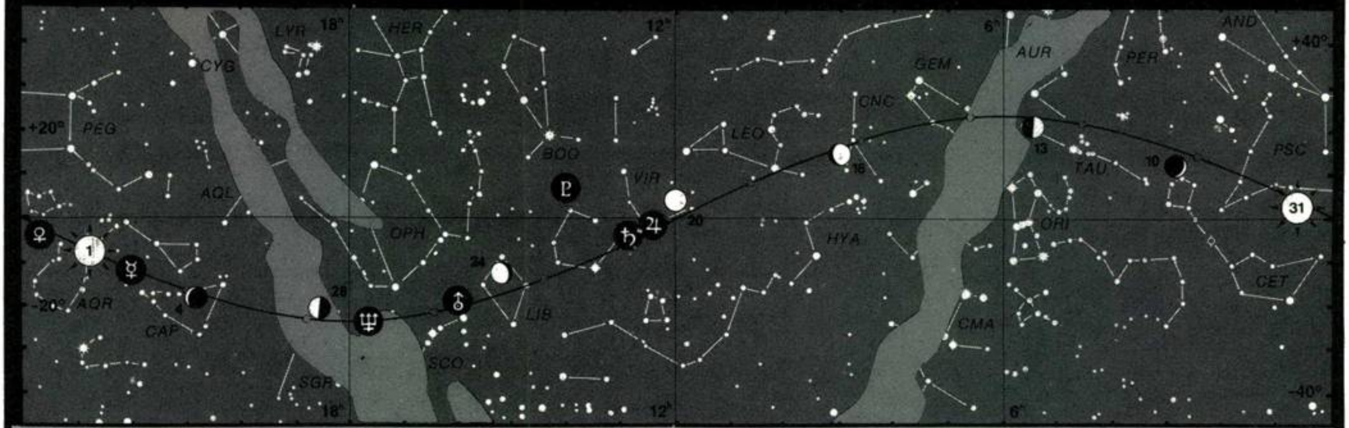
At mid-month, Vesta transits around 11 p.m. local time.

(All asteroid positions are in apparent coordinates.)

Jupiter & Saturn

In March, Jupiter and Saturn both

planetary data march 1981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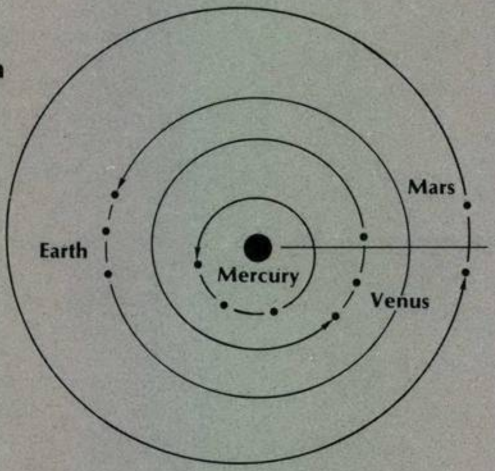
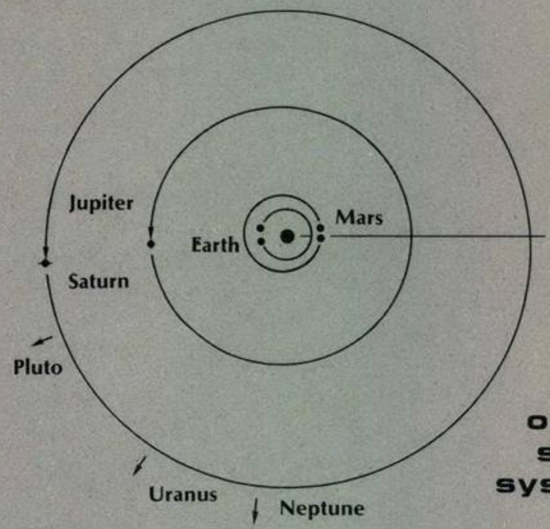
inner solar system


Earth
Mars
Mercury
Venus


Jupiter
Saturn
Pluto
Earth
Mars
Uranus
Neptune

outer solar system

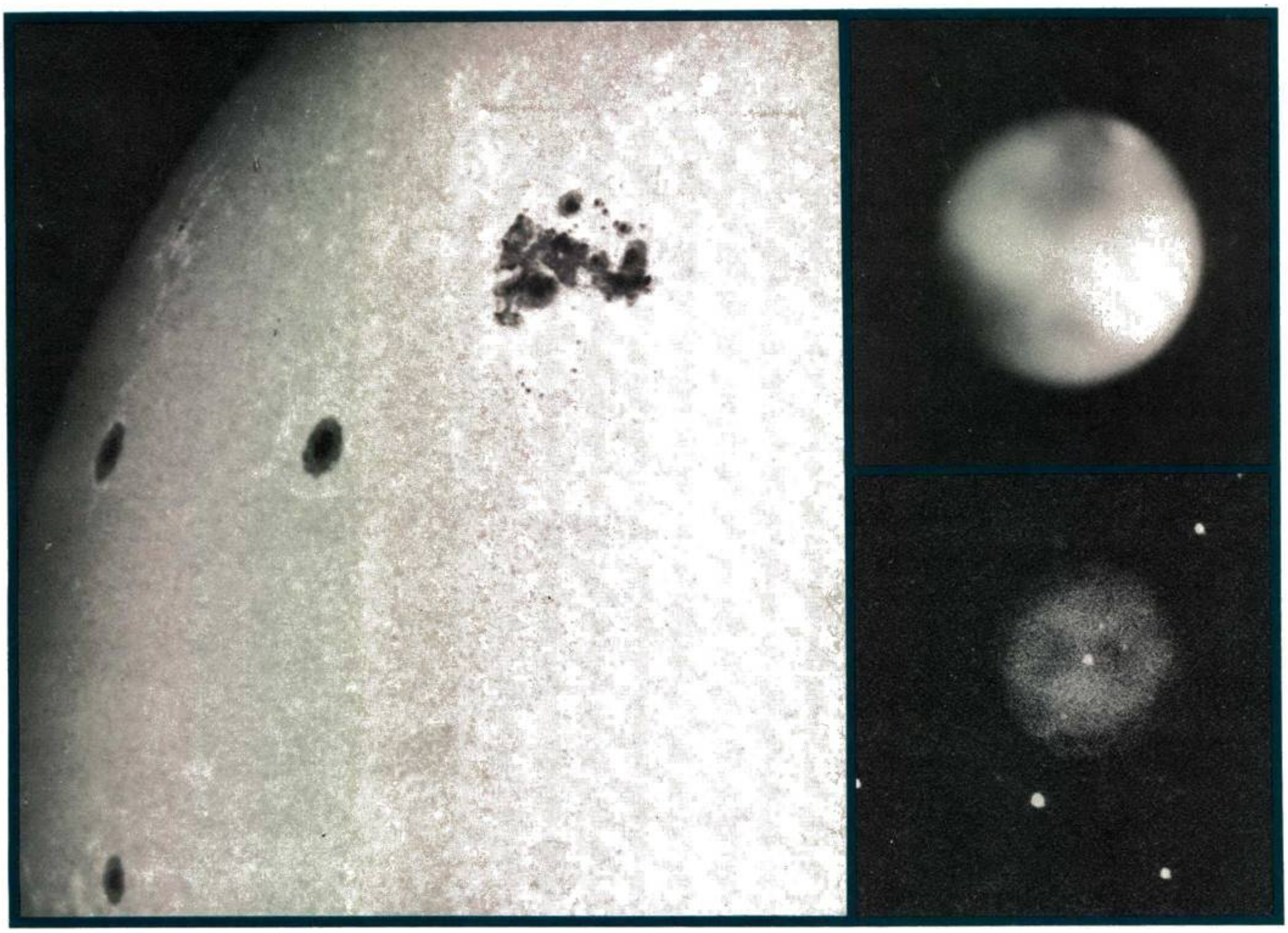
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1981.3)	Dec
Sun		10	-26.7	32.3′	--	0.99	--	--	349°20.4′	23 20.8	-4°13.4′
		20	-26.7	32.2′	--	1.00	--	--	359°18.2′	23 57.4	-0°16.8′
Mercury	☿	10	+0.6	8.0″	44%	0.83	0.45	225°38.4′	322°24.9′	21 39.7	-13°48.7′
		20	+0.4	6.8″	60%	0.98	0.47	253°47.5′	331°43.2′	22 18.2	-12°06.2′
		30	+0.1	6.0″	72%	1.12	0.46	281°41.6′	344°51.7′	23 09.1	-7°57.2′
Venus	♀	10	-3.4	9.9″	99%	1.70	0.73	332°22.5′	341°44.6′	22 56.4	-8°17.9′
		30	-3.5	9.8″	100%	1.72	0.73	4°07.8′	6°38.1′	0 28.1	+1°32.9′
Mars	♂	15	+1.3	3.9″	100%	2.38	1.39	1°15.2′	357°55.8′	23 55.2	-1°23.6′
Jupiter	♃	15	-2.0	44.0″	100%	4.74	5.45	184°15.5′	186°28.4′	12 27.9	-1°17.5′
Saturn	♄	15	+0.7	19.4″	100%	8.58	9.55	185°51.6′	186°56.1′	12 31.3	-0°30.1′
Uranus	⛢	15	+5.8	3.7″	100%	18.37	18.80	237°18.4′	239°36.1′	15 51.8	-19°56.6′
Neptune	♆	15	+7.8	2.4″	100%	30.27	30.27	262°56.4′	264°22.1′	17 37.6	-22°00.6′
Pluto	♇	15	+14.0	--	100%	29.23	30.06	202°45.9′	203°17.1′	13 52.2	+7°20.4′

moon data

New Moon	March 6 at 10:31
First Quarter	March 13 at 01:50
Full Moon	March 20 at 15:22
Last Quarter	March 28 at 19:34
New Moon	April 4 at 20:19
First Quarter	April 11 at 11:11
Perigee: March 8 at 12h	362,870 km
Apogee: March 24 at 9h	405,591 km

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times in Through the Eyepiece are UT unless noted otherwise. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on Jan. 2, then the time in EST would be 10 p.m. Jan. 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m. on March 4.



Above: Sunspots, granulation cells, and faculae spread across Jean Dragesco's photo of the Sun. Top right: Meridiani Sinus, Mare Acidalium, and the north polar cap show clearly in D.C. Parker's photo of Mars taken last March. Bottom right: The Owl Nebula (M-97) in Ursa Major was photographed by Alfred Lilge.

reach opposition within 23 hours of each other: Jupiter at 6h on the 26th and Saturn at 5h on the 27th. This puts both of them where they can be observed virtually the whole night through for most of the month.

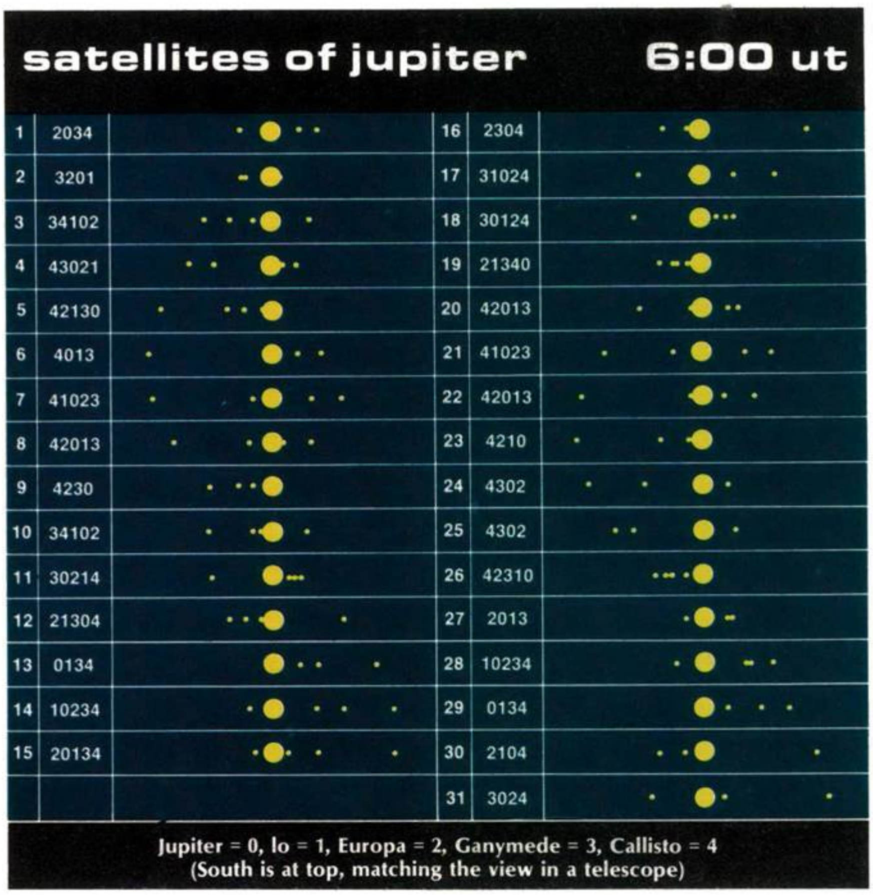
Starting a degree south of Saturn on the 1st, Jupiter's motion along the ecliptic moves it to nearly the same declination as Saturn by late in March. Take your low-power eyepiece and sweep from one to the other. Don't miss this year's opportunity to compare these two — you'll have to wait more than two centuries for them to be so close for so long.

Uranus

Beta (β) Scorpii is a magnitude 2.9 double star and the key to locating the dim gas giant planet Uranus. Center Beta in a low-power eyepiece and then swing your scope about 12 minutes of right ascension west. Look for a 3.8 arc-second dot of about 6th magnitude.

Neptune

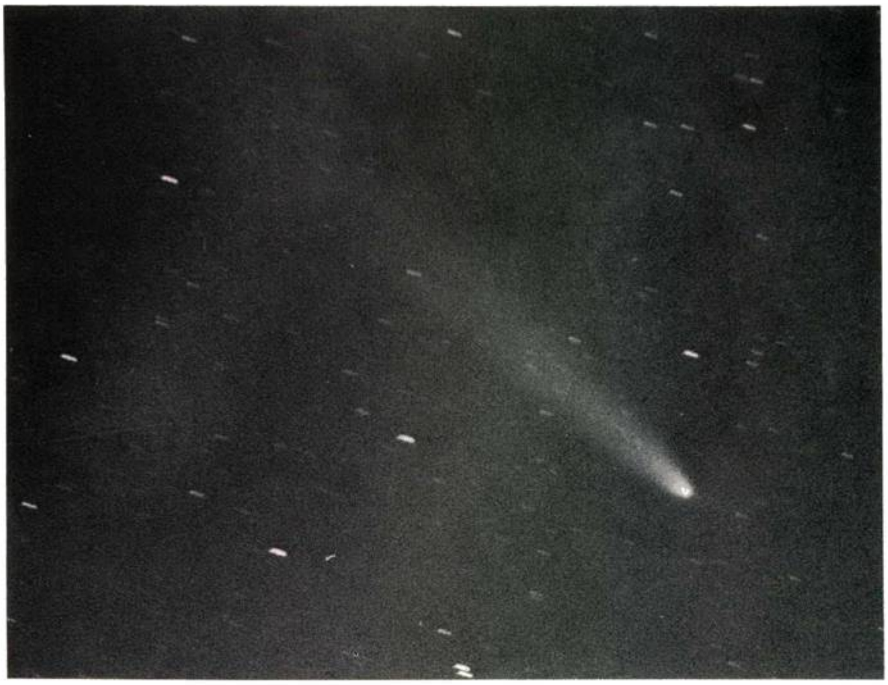
Rising about 1:30 a.m. local time on



satellites of jupiter **6:00 ut**

1	2034	16	2304
2	3201	17	31024
3	34102	18	30124
4	43021	19	21340
5	42130	20	42013
6	4013	21	41023
7	41023	22	42013
8	42013	23	4210
9	4230	24	4302
10	34102	25	4302
11	30214	26	42310
12	21304	27	2013
13	0134	28	10234
14	10234	29	0134
15	20134	30	2104
		31	3024

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



Left: M-81 is a majestic pinwheel 7,000,000 light-years distant in the direction of Ursa Major. Photo by Craig McCaw. Right: Comet Bradfield (1980t) was photographed by Gary Hug on January 8, 1980 with a 15 minute exposure. Since he guided his telescope on the moving comet nucleus, stars appear as short trails.

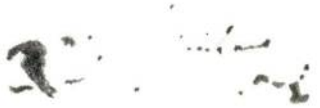
March 15th, Neptune lies 2° north and about eight minutes of right ascension east of 51 Ophiuchi, a magnitude 4.9 star. It also lies about 20′ of declination south and five minutes of R.A. west of 58 Ophiuchi, another 4.9 magnitude star. Look for a 7.7 magnitude disk, about 2.4″ of arc in diameter.

observers' report

From Douglas Craig: As I am spending a year in the Pacific, I thought I'd tell you a bit what it's like here. Watching sunsets over Moorea is a very popular pastime, so I was intrigued to read Chris Jensen's letter in the July In Focus about the "Cheshire cat smile" new moon. On the night of the 13th I saw a similar moon at 6:15 p.m. — at just about the time it set — and some 15 minutes after sunset. A quick check of the July Sky Almanac soon put to rest any ideas of a record, but such an early moon is indeed an interesting sight.

Viewing here is spectacular. The nights are as black as velvet — and warm. Furthermore, there is a nice mix of northern and southern skies, with the southern stars well up in the south.

From Jim Phillips: Only a few months ago, the Sun seemed unusually quiet, but now there is plenty of activity. I've been sketching the groups as well as photographing them. On June 29, despite 90° hot and humid weather, and despite frequent interruptions by cumulus clouds, the view was magnificent.



One spot group was on the preceding limb. I enjoyed a fine view of the penumbra of the largest spot, with delicate and lacelike detail which was very difficult to draw. Interestingly, there was a faint darkish streak in the penumbra of the large spot.

Another major group, which I called the "seahorse" group because of the shape of the umbra in the biggest spot, had small whitish oval areas in the spot penumbrae.

close-up on gemini

Gemini, with its two bright luminaries Castor and Pollux, is one of the more prominent constellations in the Zodiac. The region is also, as Olcott described it, "a rich field for the telescopist," but we would add that there is much here to please the binocular viewer as well.

The second brightest star in Gemini is **Castor**, officially designated **Alpha** (α) **Geminorum**. Castor is known as one of the most pleasing double stars in the heavens, but in reality the system is a triple-double, consisting of three spectroscopic doubles for a total of six individual stars in all. The two brightest component systems, Castor A (magnitude 2.0) and Castor B (magnitude 2.9), are currently separated by about two seconds of arc in position angle 90° (east-west). The third component, Castor C, is a dim ninth magnitude pair of red dwarfs lying 73″ away in position angle 165°. The orbital plane of the two stars comprising Castor C lies almost exactly along our line of sight, so eclipses occur every 9¾ hours. The brightness drops by half a magnitude (to 9.6) at mid-eclipse. (As a variable, the Castor C system is sometimes referred to as YY Geminorum.)

Castor C has an unmistakable orange or ruddy cast to it, but the colors of the bright duo are much more difficult to pin down. Both stars appear bright white on first glance, as expected from their spectral classifications as early A-type suns, but many observers note the presence of definite off-white tints. How do you see this magnificent stellar system?

Beta (β) **Geminorum**, better known as **Pollux**, is actually the brightest star in Gemini. At magnitude 1.2, it outshines nearby Castor, which carries the Alpha designation, by about half a magnitude. Noticeably more yellowish than its dimmer "twin," Pollux is a K0-type star. Although there are a number of faint apparent companions to the primary, it is now known that none of these are physically associated with Pollux. Just be careful that when you look for the duplicity of Castor, you don't mistakenly focus on Pollux instead!

NGC-2392 is a vivid blue planetary nebula with a bright central star. Located right next to an eighth magnitude star just two degrees southeast of the double Delta Geminorum, it is easy to find by sweeping with a low-power, wide-field eyepiece. Although its classic size is a nearly circular 47 by 43 seconds of arc, NGC-2392 looks much smaller through the eyepiece. This is because the brighter central region of the nebula is surrounded by a much dimmer diffuse ring, only visible with large apertures. Dark markings in the central region give the nebula the appearance of a face in observatory photographs, but these won't be visible in small amateur instruments. These features, however, have led to the nicknames of the Clown Face and the Eskimo Nebula for NGC-2392, and Robert Burnham, Jr. points out that the nebula "irresistibly suggests the classic and unforgettable features of W.C. Fields."

minima of algol

(times of middle of primary eclipse)

Date	Time (UT)
Mar. 3	3:07
5	23:57
23	4:52
26	1:41

The whirling cloud belts of Jupiter make a delightful sight in any telescope. Now, with the giant planet at opposition to the Sun, it appears largest, brightest, and most detailed in your eyepiece — and it's visible the whole night through. D.C. Parker's fine photo was taken in March of 1980, close to Jupiter's last opposition.

The central star is relatively bright at about tenth magnitude, and many observers find it appears even brighter than that. In six-inch and larger telescopes, the view is exceptional — a bright bluish haze surrounding a sharp central sun. If you haven't yet seen the Eskimo Nebula, put it on your list of "musts"!

Delta (δ) **Geminorum** is a double star consisting of a 3.5 magnitude primary attended by a much dimmer eighth magnitude companion 6″ away in position angle 220°. The great range of brightness makes it difficult to see any color contrast, but the spectral types of F0 (primary) and K6 (secondary) suggest a definite difference. The primary star is intrinsically eight times as bright as our Sun, while the secondary, orbiting at a distance of 95 astronomical units, is a dwarf star only one-ninth as luminous as the Sun. If our Sun had such a companion in such an orbit (over three times the distance of Neptune), it would shine in our sky as a brilliant star of magnitude -14.5, about five times the brightness of the Full Moon.

The primary of the double **38 Geminorum** is also an F0-type star, this time with a G4-type dwarf companion 7 arc-seconds away in position angle 150°. The orbital period is estimated to be about 3000 years.

20 Geminorum is a well-matched pair of seventh magnitude stars separated by a healthy 20 seconds of arc (position angle 210°). Although this double shares a common proper motion, it is not known if they are physically associated since no orbital motion has been detected.

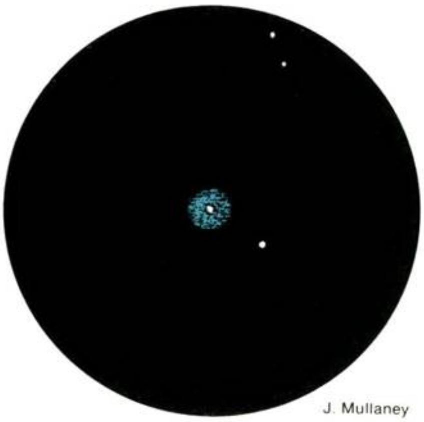
Zeta (ζ) **Geminorum** is one of the brightest Cepheid variable stars. Its period is 10.152 days, during which time its brightness changes over a range of half a magnitude. The usefulness of Cepheid variables in determining the distances to nearby galaxies depends on their being luminous enough to be observed at such great distances, and they are indeed: Zeta Geminorum is actually nearly 6000 times as bright as the Sun when it is at maximum light. If you wish to observe Zeta's variations with the naked eye, compare it with nearby Kappa (κ) Geminorum (magnitude 3.6) and Upsilon (υ) Geminorum (magnitude 4.1).

A variable star of a very different kind is **Eta** (η) **Geminorum**, a pulsating red giant with a semi-regular period of 233 days. Eta is also a visual double star, but this fact is not noted in our table because the 6.5 magnitude companion lies only 1.5″ distant and is difficult to observe in small aperture telescopes. If you have eight inches or more, though, you might look for it at position angle 262°.

Saving the best for last, we now turn to the spectacular open cluster **M-35** with its nearby companion, **NGC-2158**. M-35 is visible on a dark night to the unaided eye as a faint, fuzzy patch — and it's a superb sight with even the slightest optical aid. Large and uniform, it needs an eyepiece with at least a one degree field to be appreciated fully. Pickering included it in his list of the finest irregular clusters, noting, as have many other observers, that its "stars are arranged in part in curved lines."

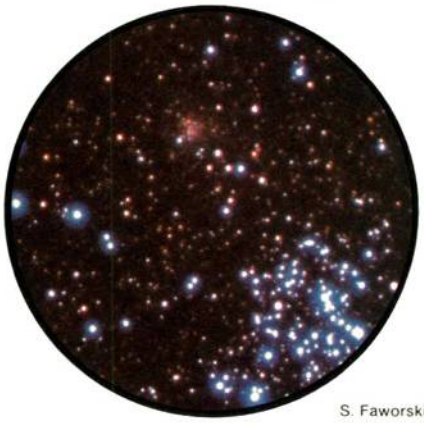
NGC-2158 is located only half a degree southwest of M-35 and can be found by offsetting slightly from that larger cluster. Very rich but small and very faint, NGC-2158 will look like an unresolved globular to most observers. With individual stars ranging downward from 15th magnitude, a large aperture is necessary to resolve its dim glow into stars. Although this distant cluster has been traditionally classified as an open cluster, the *Revised New General Catalogue* now lists it as a globular. Most astronomers regard it as an intermediate type between the open and the globular clusters. Viewing NGC-2158 carries us out over 15,000 light-years to the very rim of our Galaxy — a grand journey indeed!

NGC-2392



J. Mullaney

M-35 and NGC-2158

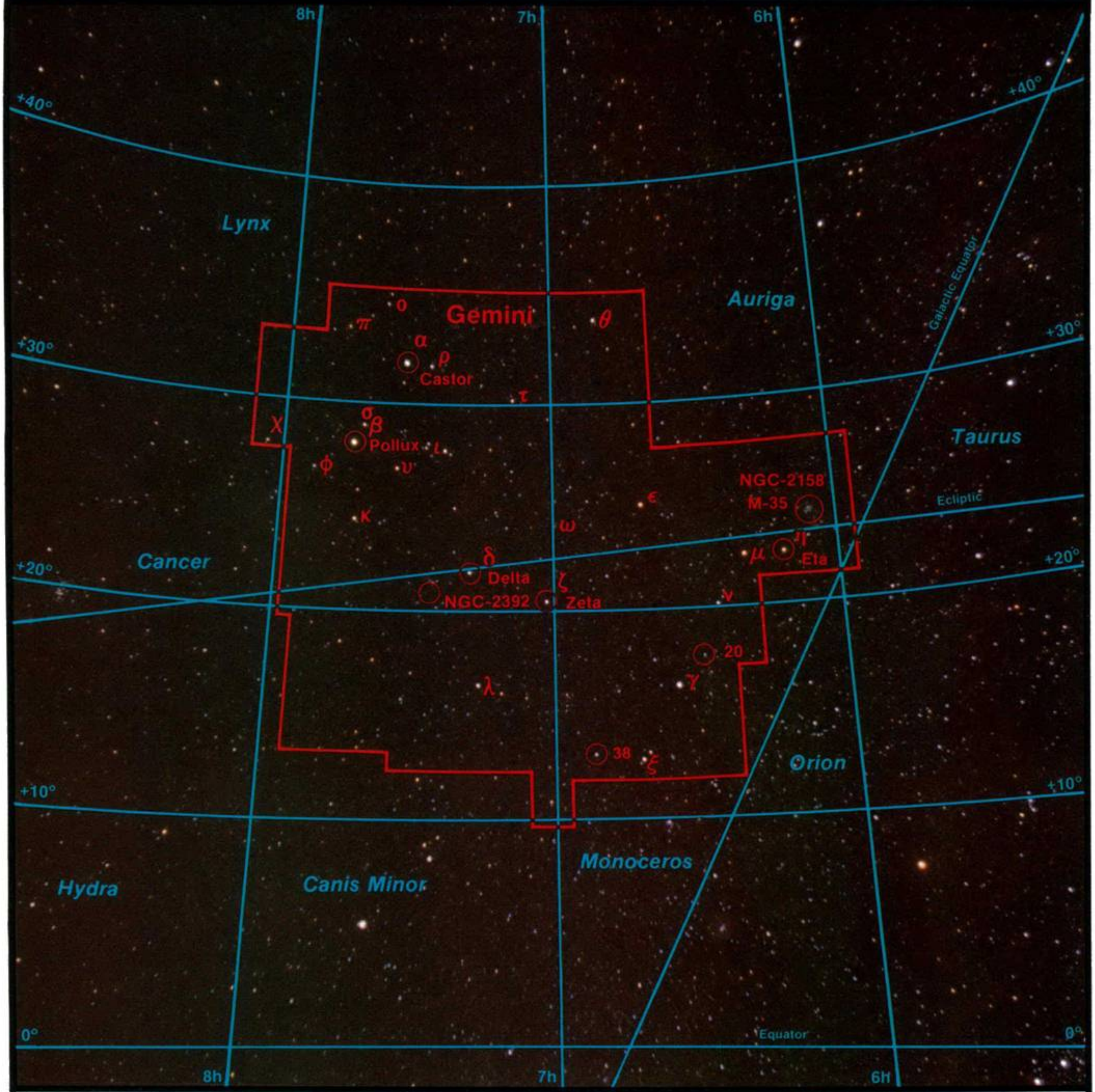


S. Faworski

Map by Dewey Schwartzenburg

gemini

Photo by R. Provin & B. Wallis


8h
7h
6h
+40°
+30°
+20°
+10°
0°
Lynx
Auriga
Gemini
Taurus
Cancer
Orion
Hydra
Canis Minor
Monoceros
Galactic Equator
Ecliptic
Equator
Castor
Pollux
NGC-2158
M-35
Eta
Delta
NGC-2392
Zeta
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Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1981)	Dec.
NGC-2158	●	12	4′	06 04	+24°06′	06 06	+24°06′
M-35	○	5.3	40′	06 06	+24°20′	06 08	+24°20′
Eta (η)	m★	3.1-3.9	233d	06 12	+22°31′	06 14	+22°31′
20	★^{2}	6.7,6.9	20″	06 29	+17°49′	06 31	+17°48′
38	★^{2}	4.7,7.6	7″	06 52	+13°15′	06 54	+13°13′
Zeta (ζ)	m★	3.7,4.2	10.15d	07 01	+20°39′	07 03	+20°36′
Delta (δ)	★^{2}	3.5,8.1	6″	07 17	+22°05′	07 19	+22°01′
NGC-2392	■	8.3	47″x43″	07 26	+21°01′	07 28	+20°57′
Alpha (α)	★^{3}	2.0,2.9,9.1	2″,73″	07 31	+32°00′	07 33	+31°56′
Beta (β)	★	1.2	—	07 42	+28°09′	07 44	+28°04′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
m★	*Regular Variable*
n★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

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C-90 Spotting scope	279
C-90 Astro scope	409
C-90 Astro, tripod, wedge	555
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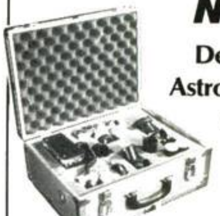

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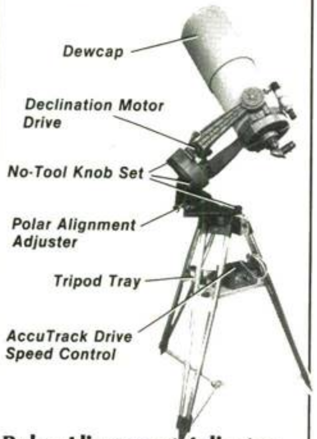

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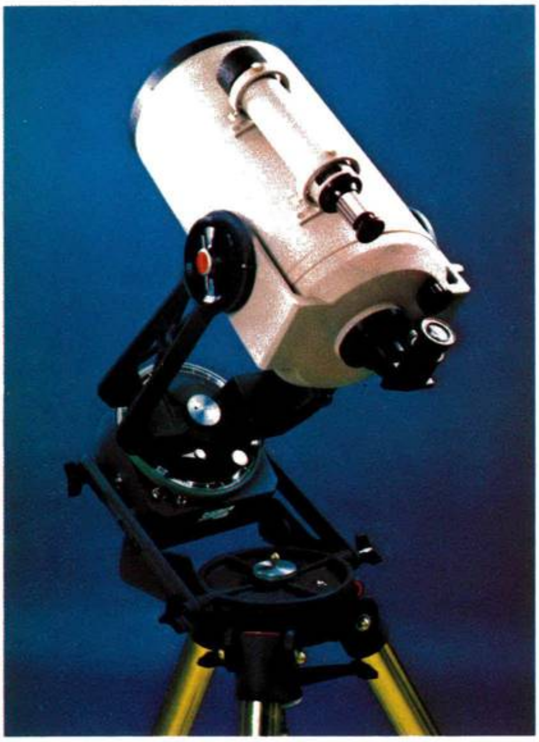
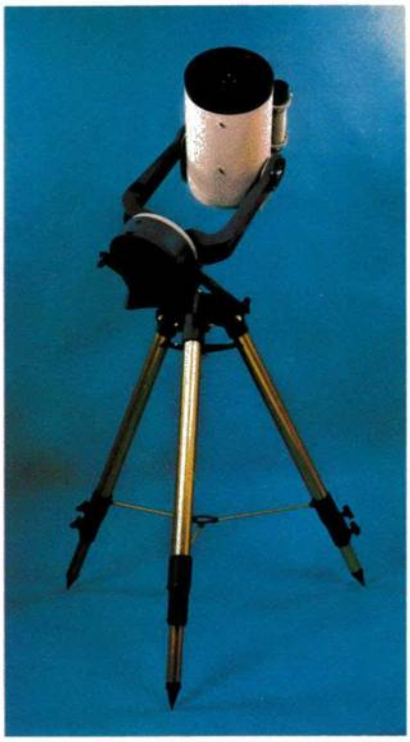


Rear view of the Dynamax 8 mounted on Dynamax Field Tripod



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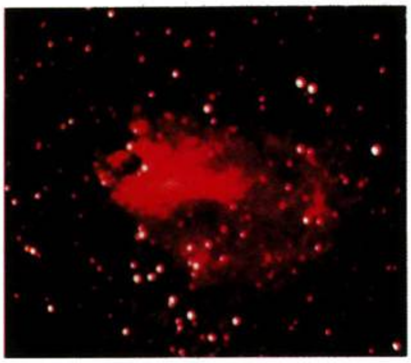

The Omega Nebula (M17) as photographed through the Dynamax 8.

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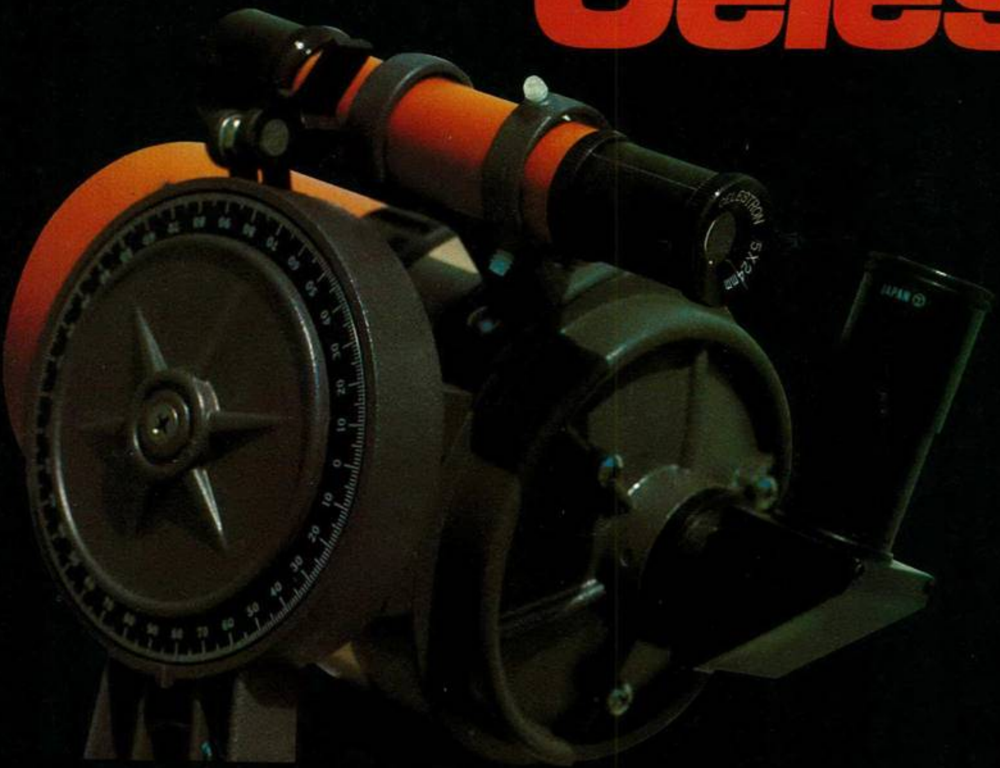

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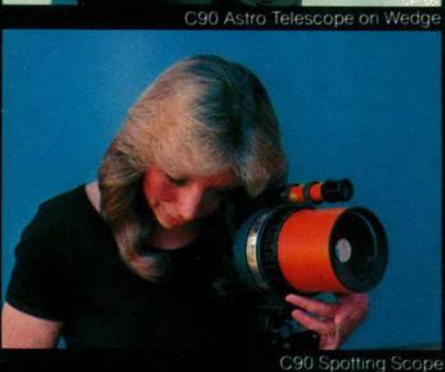
C90 Astro Telescope on Wedge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